Megatrends for 2021-2030

Roberto Saracco - Digital Reality Initiative

This eBook has been produced as part of the Digital Reality Initiative of the IEEE Future Direction Committee. However, the content is of sole responsibility of the author. Segments of this ebook have been published on the FDC Blog in the November-December 2020 timeframe. Comments on the Megatrends have been submitted by several parties both on the blog, on Linkedin and as result of presentations that the author gave. These comments have been taken into account in the preparation of this ebook.
20 of the presented Megatrends have been inspired by the list of Megatrends for this decade written by Peter Diamandis. However, the discussion of all Megatrends has been done by the author.

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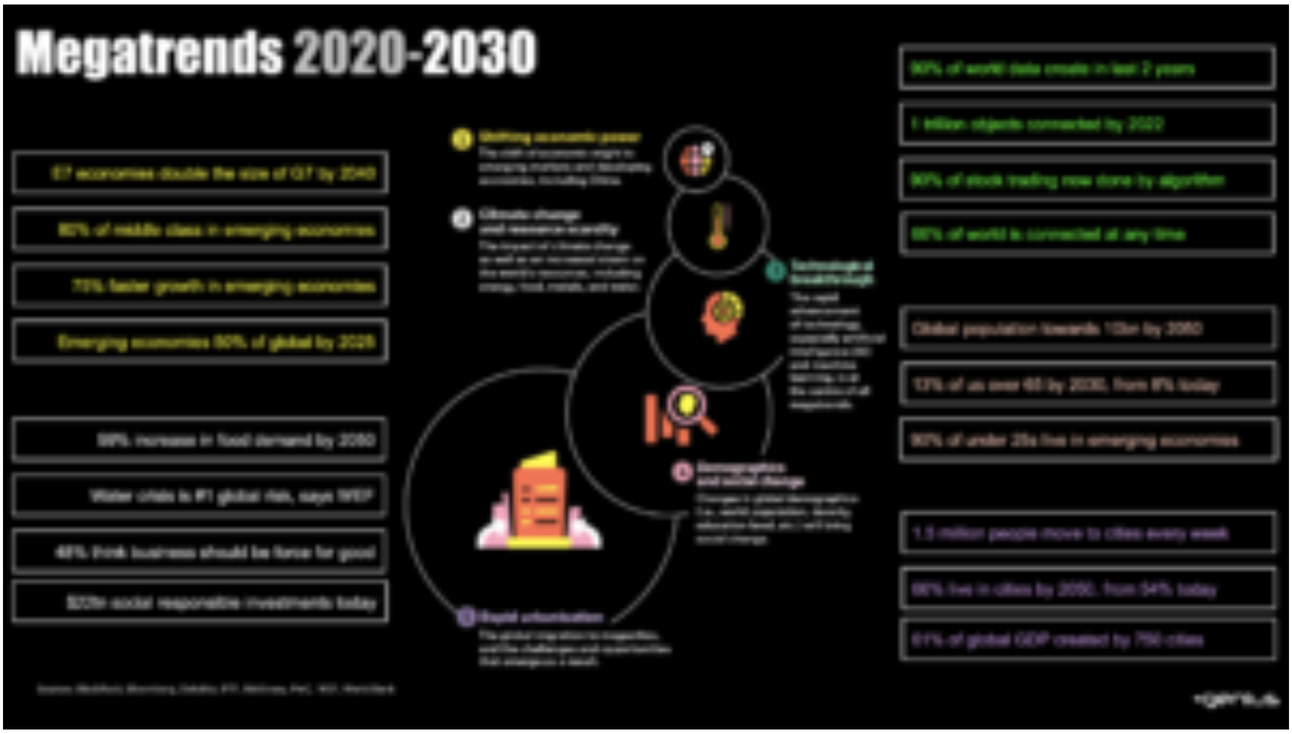


Fig. 1 Megatrends foresight for this decade with special focus on economy. The prediction did not take into account the upheaval created by Covid-19. Image credit: Genius, based on data from BlackRock, WorldBank, Bloomberg, Deloitte, WEF, IFTF, McKinsey

The ongoing pandemic was nowhere to be seen in 2019 (although several people in the previous 10 years have been warning that one pandemic was due -statistically we get a major one every 100 years) and hence it was not taken into account in laying forecast for the incoming decade. The pandemic clearly disrupted short term forecast but Megatrends spanning the next ten years may not have been affected significantly. Clearly some tuning is required, like taking into account acceleration or slow down following the pandemic and the countermeasures taken, but most of the forecasts can still be considered valid.

In this ebook I will be looking at the optimistic Megatrends proposed by Peter Diamandis that will be discussed in an event on January 24th 2021.

Before looking at the proposed Megatrends I plan to present and briefly discuss the ones resulting from the analyses of forecasts coming from the WorldBank, WEF and a few Intelligence Agencies (see picture). They are useful to set the scene to Peter's Megatrends that are more focussing on the expected impact of technology evolution.

1. the Emerging economies of the 7 Countries forming the E7, **China**, **India**, **Brazil**, **Mexico**, **Russia**, **Indonesia** and **Turkey**, will double the size of the G7 economies, Canada, *France*, Germany, Italy, Japan, the United Kingdom and the United States, by 2040. Notice that the classification of Emerging Economy needs some revision, given that China this year, according to the IMF, has already surpassed US as the largest economy in the world. Additionally, the pandemic has accelerated China's relative growth, since it has been the first major economy to recover after the pandemic, with an expected growth in 2020 of 2% (way

lower than the usual growth, but a significant upswing from the 6.8% decrease marked in the first quarter of 2020);

2. Emerging economies will be experiencing a 75% faster growth than G7 economies. This is going to shift the established consumption of goods and influence the design of new products, also considering that the consumer market is driven by the middle class and by the end of this decade 80% of the middle class will be found in the E7. Also consider that the E7 will represent 50% of the World GDP by 2025. Their markets will likely steer the evolution in the second part of this decade;
3. The global population keeps growing. It is expected to reach 10 billion in 2050. There were 7.7 billion people at the end of 2019 and according to the world clock there are at the end of 2020 7.835 billion people. By 2030 the population over 65 yo is expected to reach 13% of the total population (compare this with today's 8%). This is likely to put a strain on healthcare. Also notice that the age range differs in various geographical areas with 90% of people under 25 yo living in emerging countries. This is another factor creating strong imbalance across Countries;
4. The growing population will increase food demand by 59% in 2050 and there is a drinkable water looming crises. Water, food and critical resources (raw materials) are a potential danger for the wellbeing and for a peaceful living. As shown in following sections some feel we have the technology (or will have) to face and meet these challenges. The general consensus is that technology evolution will use artificial intelligence as a tool to accelerate progress.
5. The growth of population is not going to be evenly distributed. Also, urbanisation will continue at an accelerated pace. Every week 1.5 million people move to cities and in 2050 66% of the total world population will live in cities (compare with today 55%). Additionally, it is expected that 61% of global GDP will be produced by 750 cities. This is leading to the creation of mega cities with tremendous need for efficient infrastructures.

These economic/societal Megatrends are leveraging more and more on a digital economy and digitalization in its many forms. 90% of world data has been created in the last two years and this window is going to become shorter as we move into the future. Many activities are already performed in the cyberspace (90% of stock trading is now done by algorithms) and more and more objects are connected to the cyberspace (1,000 billion objects by 2022).

These trends are not just leveraging, they are also steering the technology evolution and change the way we live.

1. *Global Abundance*

Fig. 2 [Increase in yield]() in cereal production against a stable use of land. Image credit: WorldData

Although we usually hear dark predictions on shortage of food for a world population that keeps increasing, production data tell a different story. As shown in Figure 2, productions is actually improving faster than the population growth (this is for cereals, it is true for several other areas, with the exception of fishing and cattle). The big issue is related to climate change and to the transportation of products to the point of consumption.

Climate change may lead to sea level rising, the flooding of areas densely populated as well as agricultural areas that produce a significant amount of food. At the same time, the rise in temperature can turn areas that are not suitable for crops today into areas that can yield a good harvest. Notice that the shift, if it were to happen, would create huge problems as people will have to move from one place to another, the current flow of migration is nothing in comparison to what may happen if sea rise becomes significant. An example is given in figure 3. More examples can be found [here]()

Fig. 3 Map showing the effect of a 1 m sea rise in Bangladesh, something that might happen by 2030. Notice that the impact is not contained to the sea rise (permanent flooded area) but also by the inundation cause by increased storm surge (monsoon and typhoons). The blue area is today a living place for 15 million people and a very fertile area. Image credit: UNEP/GRID-Arendal

Transportation of products is also another huge hurdle. It doesn't help that we have abundant crop in a certain area if we are not able to distribute the surplus in areas that are experiencing food shortage. Sub-Saharian Africa is a point in case.

Logistic chains have become very effective, actually this is one of the main significant evolution in the past fifty years, and for sure one that has changed the wellbeing of people as well as the distribution of work (off-shoring is totally dependent on the efficiency of the logistic infrastructure). Yet, reaching certain areas in an effective way (low cost, short time) remains a challenge and it may remain so in the foreseeable future.

This is why alternative, complementary solutions are needed, like moving crops closer to the consumer market. I'll address this in a following section.

Peter Diamandis, in [his interesting blog](), placed at the top of his Megatrends list the reduction of poverty as an indicator of the growing global abundance of resources but I feel that affordable food availability (and water) is at the core of the reduction of extreme poverty, that is why I started this discussion on Global Abundance from the availability of food: this is one of the basic needs we face, along with availability of fresh, clean water, a topic I will address in conjunction to energy availability.

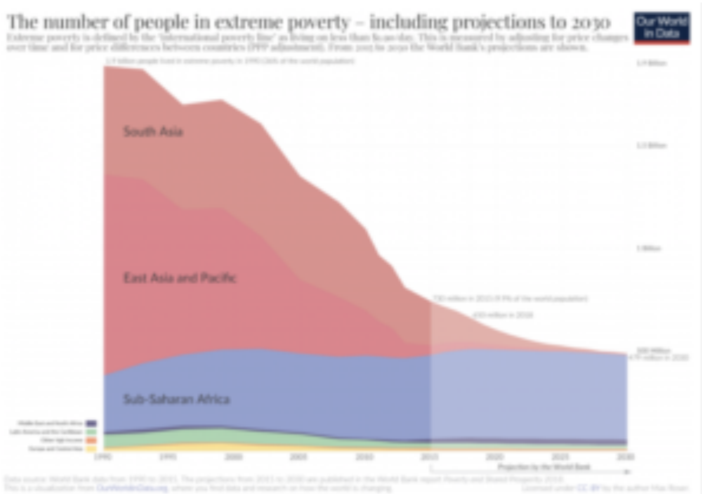


Fig. 4 Graphic showing the decrease of extreme poverty, defined as living with less than 1$ a day per person. Significan progress have been made over the last 30 years worldwide with the exception of sub-Saharian Africa where the situation has actually worsened. Image credit: World Data base. Graphic rendering by Our World in Data

I do agree, of course, with him that the reduction of extreme poverty is a very important indicator.

As shown in figure 4 the progress made in the last 30 years has been significant but the expectation is not rosy for this decade, since the big sub-Saharian area is not expected to show significant progress. One of the reason is the difficulty of having effective logistic chains there, the economic crises and the political situation in the region (these three factors go hand in hand and a solution can only come by addressing all of them in synch).

Apart from this (big problem) the expectation is that global abundance will be reflected by a generalised improvement of life and wellbeing in most parts of the world with more and more people having access to better food, clean water, better education and increased economic possibilities (that in turns will fuel the market, as noted in the previous section forecasting the rapid uptake of E7).

Interestingly, Peter attributes this overall increase to:

- low cost communications, a trend we have already seen in the past decade, with affordable cell phones (now you can get a smartphone with a 6.5" screen in India for 85$, a brand new Nokia cell phone goes for 10$) and very low internet rate (in India the current lowest plan gives you 2GB of data and unlimited calls for 1.4$ for four weeks!);
- ubiquitous AI through the cloud, lowering the cost of AI (we are already seeing AI on-demand services that will be fuelling more and more applications in this decade -AIaaS: AI as a Service). Ubiquitous Internet access will bring AI within reach of every person in the world (a topic we are addressing in 2021 in the DRI - Digital Reality Initiative);
- access to higher education and better healthcare leveraging on tele-services and on AI in the cloud. This dramatically lowers cost, making advanced high quality service accessible and affordable to people all over the world;
- the Digital Transformation that by moving activities and value to the cyberspace makes everything more affordable and easier to reach by anybody, More than data: affordability plays both on the consumer as on the production/offer side. This creates a virtuous cycle of continuous, rapid, innovation and a continuous lowering of price that in turns fuels demand and adoption as described in the "just published" Digital Transformation White Paper by DRI.

*2. **Global gigabit connectivity at ultra-low cost***

Fig. 5 A rendering of CubeSat deployed in orbit to provide high bandwidth communication coverage all over the planet. Image credit: Alén Space

This Megatrend is actually the convergence of three: "global", "gigabit " and "ultra-low cost". The quest for coverage and for performance is nothing new, as a matter of fact. The novelty is in the "quality" and "quantity" foreseen by this trend.

Connectivity has kept improving over the last 150 years. However, it is only in the last 20 years, with the advent of low cost wireless technology (particularly on the handset side, the cellphone) that we have see a tremendous growth.

What used to take 50 years in terms of usage adoption has been squeezed into a few years. There are now 5.5 billion people connected via a cellphone, 90% of them with a smartphone.

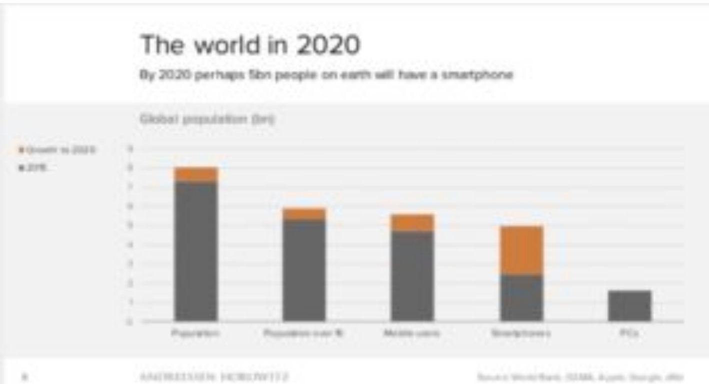


Fig. 6 An interesting representation of the world population vs the number of mobile users, smartphones and PC. Notice that if we compare the number of mobile users with the number of people age 10 and older (second bar) we get almost a ono to one relation, 5.8 vs 5.5 billion. Also notable the increase mobile users vs increase in population in the 2015 (grey) and 2020 (orange). The acceleration is clear. Image credit: World Bank

It is no more just about people. Actually, if we look at the numbers, objects connectivity is already dwarfing people connectivity by number of devices and by number of transactions (not in terms of bandwidth: our usage of bandwidth for movies keeps the bandwidth usage on our side but this will also change in the coming years as more and more streaming video from safety cameras will take the upper hand in bandwidth usage).

In this decade connectivity is expected to increase further in two dimensions:

- broader area of coverage, with expectation to have full planet coverage by 2035 accessible through normal consumer cellphones (today to access satellite networks, the only ones providing full coverage, a special - expensive- phone is required). This is expected to be achieved by new generations of satellites (like OneWeb planning to have 48,000 satellites in its constellation, Starlink, already serving US and Canada with 540 satellites and expected to expand coverage in 2021/22 once 1,500 more satellites will be deployed), both low orbit constellation and cube-satellites constellation, and the capabilities of cellphones to operate in the THz band, expected to become reality with 6G;
- higher bandwidth delivered through higher spectrum availability (because of higher frequencies, in the microwave range -above 300GHz in the next decade and in the mm-wave

range 30-300GHz in the second part of this decade) coupled with more dense networks (higher number of access points, 10 to 1,000 times the ones existing today, with the higher multiplier effective with the deployment of 6G and networks dynamically set up from the edges).

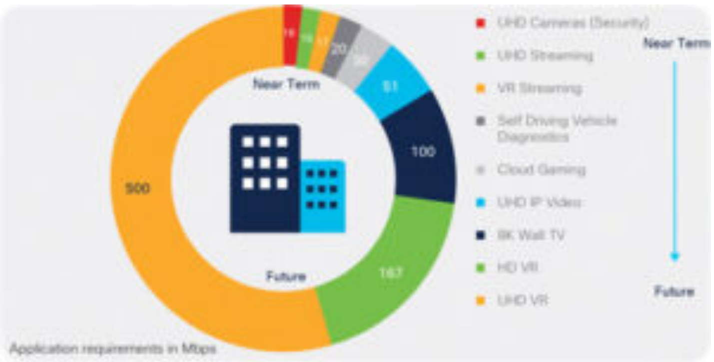


Fig. 7 Expected use of bandwidth by residential customers. Figures are expressed in Mbps. Image credit: Cisco

If "global" is easy to understand, the "gigabit" part is not so straightforward because it raises the question if "gigabit" connectivity will make a difference. There are then sub-questions like "for whom" and "who will be willing to pay for it and how much" but these latter can be superseded by the third forecast, i.e. "at ultra-low cost".

As it happened in the past we can assume that once increased bandwidth is available someone will find a way to exploit it and that eventually many people will be using it.

The graphic in Figure 7 presents a forecast from Cisco on the possible bandwidth demand by future applications, in temporal order (from near to far down the lane):

- Ultra-high definition security cameras: 15 Mbps
- Ultra-high definition streaming (4k): 15 Mbps
- Virtual Reality streaming: 17 Mbps
- Self-driving vehicles diagnostics: 20 Mbps
- Cloud Gaming: 30 Mbps
- Ultra-High definition IP Video: 51 Mbps
- 8K wall television: 100 Mbps
- High Definition Virtual Reality: 167 Mbps
- Ultra-High Definition Virtual Reality: 500 Mbps

Some of the above applications may require low latency (<10ms) or very low latency (<2ms) and will therefore require edge computing and edge / peer-to-peer communication, hence a quite different network architecture that, in principle, is already possible with 5G but then will surely be implemented for 6G.

Delivering Gigabit capacity to the single user (not to a single cell) requires very dense networks, and of course adequate technology. On the wireline side the optical fibre can deliver multiple Gbps already today, On the wireless side we need sufficient spectrum to funnel 1 Gbps. Considering 20 bit per Hz (a very very high spectral efficiency, never reached in normal conditions were a 4-6 bit per Hz would be considered as a very good efficiency) to get 1 Gbps you need 50 MHz spectrum availability (today's 5G allocated spectrum in Italy has a maximum of 80 MHz and that is for the whole cell, not for a single user!). Hence the need to use mm-waves and μm-waves (in the THz range). These allow allocation of a broad spectrum. The evolution of electronics will make this feasible in the last part of this decade.

Recapping: "global" and "gigabit" are reasonable targets. What about "ultra-low cost"?

Here is where I feel it gets really interesting!

If we look back we can see that the shift from wireline to wireless has dramatically slashed the cost of delivering bits. This is due

- first, to the fact that wireless infrastructures can scale (almost) in synch with demand. When traffic demand grows you can deploy one more cell, and then another and right where it is needed. This makes investment much more effective.
- second, to the shift of (part) of the infrastructure investment on the customer. In fact, the cell phone and smartphone are network equipment, they carry out actions that once were part of the infrastructure, like digitisation, access selection, ... Smartphones represent something like 70% of the overall cost of the end-to-end wireless infrastructure. Hence, the telecom Operators are covering only 30% of the cost, whilst in a wireline infrastructure they have to sustain 100% of the cost!

This is decreasing the perception (and reality) of cost to the end user. As the cost of the smartphones decreases so does the cost of connectivity.

This trend will continue in this decade and it will have a further acceleration by the end of the decade, beginning of the next, as communication will start to be provided by the edges (networks deployed by third parties that are not interested in charging for the access) and by objects themselves. 6G will be the first system designed to create edge networks, in part formed by meshing networks created by objects. This is what will lead to ultra-low cost connectivity.

3. Increased lifespan

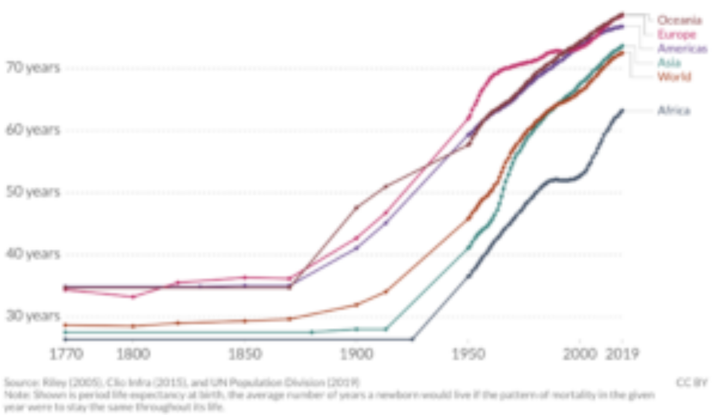


Fig. 8 Lifespan, on average, has been growing amazingly fast in the last century. The graphic shows the life expectancy at birth in the five continents and the world average. Image credit: Our World in Data. Data sources: Riley, Clio Infra and UN

Humankind lifespan has been stable, life expectancy was around 30 years for most part of the recorded history, probably less in the hundreds of thousands of years we have no written record. This relatively short life span didn't mean that a few people couldn't live longer, we have credible written report of people living into their 60ies and even 80ies but that was the exception.

This changed in the middle of the XIX century in Europe and in the Americas and at the beginning of the XX century in Asia, whilst Africa had to wait till the 1930ies to see the beginning of an increase in life span.

Although we often associate this increase with the progress in medicine, the reality is that the first increase in lifespan, until some 50-80 years ago was the result of **clean water**. It is only in the last decades that medicine has become a significant factor in the lengthening of humankind lifespan.

In figure 9 the world map rendering with colour based on expected lifespan in 1800, 1950 and 2015: the redder /yellowish the colour the shorter the expected lifespan.

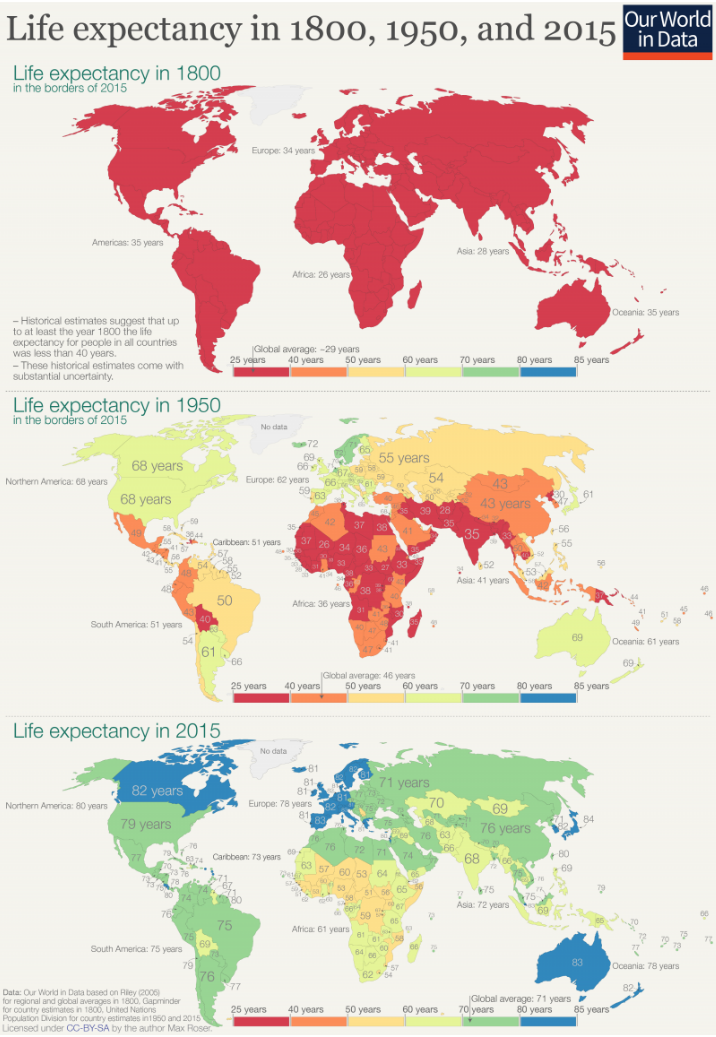


Fig. 9 Snapshots of the world in the 1800, 1950 and 2015 showing life expectancy. Image credit: Our World in Data

In the last decades medicine has become an important factor in extending our lifespan.

Peter Diamandis reasoning in formulating this Megatrend is that in the coming years medicine will be able to extend our life, and he predicts that by the end of this decade we will see a 10 years increase. That is a daring prediction that might be difficult to achieve, particularly in those areas where we have reached an expected lifespan exceeding 80 years. I have no doubt that in Africa and in several developing Countries in Asia, where the lifespan is in the 6oies and 70ies, we will see a 10 year increase, but moving from 80 to 90 or 85 to 95 (on average!) is way trickier.

In his blog Peter identifies in the progress of technology applied to healthcare this outcome. In particular he lists these technologies as the ones that will have a crucial impact in this decade:

- Stem cell supply restoration. These are the cells that can be used to create any cell in our body, they are not differentiated and have the potential to replace cells that have been dying out without being replaced by cells of the same type -a cause of ageing.
- New drugs, including GDF-11, Senolytics, NMD/NAD+, look promising but one should be cautious since, so far, they have shown some age extending capabilities in the labs (on mice an extension of 10 to 15% of the life span has been demonstrated but we do not know if that would replicate in humans nor we understand possible side effects...).
- Machine Learning and AI in general are going to provide enhanced tools to pharmaceutical research, making possible to test in the cyberspace the potential of new molecules and using "organ and body on a chip" to accelerate in-vitro testing. Digital Twins may play a crucial role in the acceleration and in the personalisation of drugs.
- Genome sequencing, CRISPR technologies, AI, quantum computing and cellular medicine are converging accelerating the discovery process and clinical trials evaluation.

In general we are starting to see a flattening of the curve (see figure 8 and look at the curves representing the life span extension in Europe, Oceania and America) so it is obvious that something "new" would be needed to further extend humankind lifespan. The technologies listed above may be that "new" that can change the rules of the game.

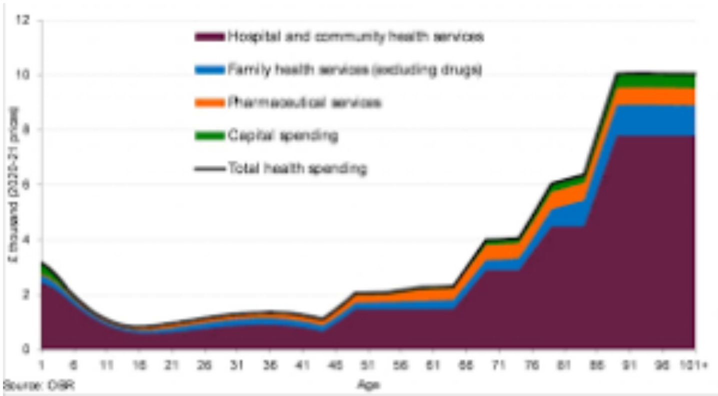


Fig. 10 Graphic showing the [increased expenditure per person as age increases](). Image credit: Office for Budget Responsibility, UK

At the same time a word of caution should be given, to take into account ageing population side effects on society and economy.

As shown in Figure 10, the cost per person increases significantly with age. It is nevertheless important to notice that usually the highest expenditure is in the 6 months preceding death, so it is not necessarily a function of age (although as we get older we are more likely to suffer from multiple pathologies, adding to the cost of healthcare).

One of the goal of researchers involved in the quest for longer lifespan is also the extension of good health, so that should take care, at least in part, of the increasing cost.

There are also societal implication in the lifespan extension, like the potential increase in world population and the need to increase the working-life time. This in turns requires a re-thinking/re-planning of social security/retirement. Notice that I am not saying that extending our life (in good health) is bad, not at all. I am just pointing out that if this Megatrend gets real we are going to face issues that need to be solved in the next ten years and ten years in societal domain is a very short time.

4. *Age of Capital Abundance*

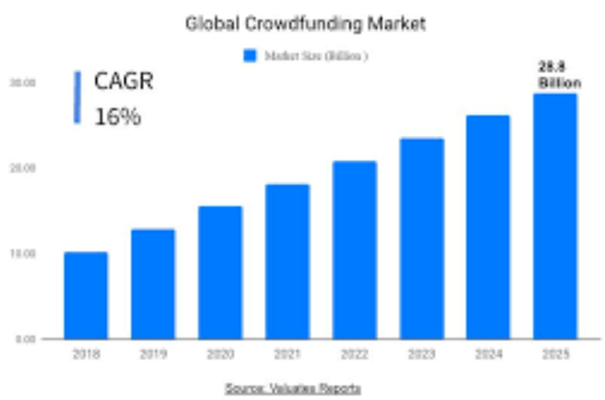


Fig. 11 Crowdfunding keeps rising at a 16% CAGR and it is expected to reach 28.3 B$ in 2025. Image credit: Valuates Reports

The global increase of wealth is creating a capital abundance that together with money dematerialisation, online transactions, market accessibility and funding platforms facilitate access to capital. Crowdfunding, see figure 11, is an example of the power of access to distributed capital. Notice that although this relatively new capital access is growing rapidly and it is indicative of a new wave of funding, its global value is very very small when compared to the overall money circulation. It is, nevertheless important in showing the impact of Digital Transformation in Finance. Long gone are the times of the industrial revolution were capital was concentrated in a few hands that basically took decision on its investment.

The development of an effective banking system has made money within the reach of many more people (of course the system was and is far from perfect, with the funny but sadly true statement that banks tend to give money to those that already have money!).

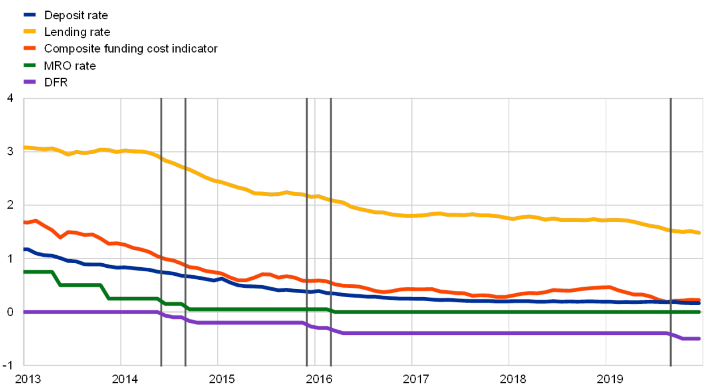


Fig. 12 The vertical black lines indicate the five cuts in the DFR into negative territory, from 0 to -0.1% in June 2014, from -0.1% to -0.2% in September 2014, from -0.2% to -0.3% in December 2015, from -0.3% to -0.4% in March 2016, and from -0.4% to -0.5% in September 2019. Latest observation: December 2019. Image credit: European Central Bank. Sources: ECB and ECB calculations.

In these latest years we have seen that the cost of borrowing money has decreased to the point that in some cases (in banking transaction) it has actually become negative (see figure 12).

The abundance of money is both a cause and a consequence of this situation. As more money becomes available the interest rate goes down, and conversely as the interest goes down money becomes more affordable.

The availability of "cheap" money clearly has an impact on borrowers and lenders;

- borrowers find quick and cheap availability of money to sustain investment, hence they tend to accelerate investment and this, in turns, stimulates innovation. Small amount of money can be found via crowdfunding (previously mentioned) or through specific Government sustained measures, whilst large investment takes the form of more structural agreements with long terms investors (banks and pension funds, as an example);
- lenders look for investment that can generate returns in the medium long term, since short term investment will lead to a "negative" return and tend to become part of the investment (i.e. buying shares rather than just lending money).

This money availability, coupled with long term returns is particularly conducive to support infrastructure building (since these have a longer lifespan and can ensure returns over several years, even decades.

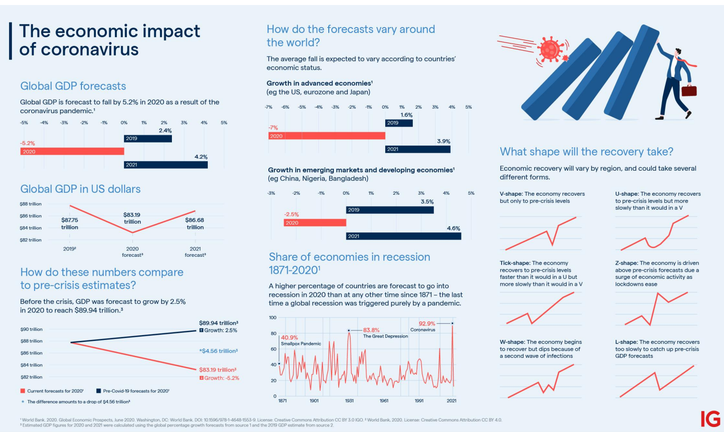


Fig. 13 An overview of the effect of the pandemic on the economy. Notice the slump in GDP (that is however different in different regions) that is clearly going to affect investment. Also notice the various possible types of recovery (the so called V, U, W, Z and L shaped recovery). Image credit: IG.com

We are seeing this phenomena in the growing interest in funding radio towers, a business that is seen by investors as long term and likely to generate a steady return. The result is that companies in that business find themselves with an easy access to funds that can sustain a redesign of the tower market, placing more intelligence in the towers and thus accelerating the shift towards edge computing, smart antennas and networks at the edges.

The overall situation has clearly changed as the pandemic keeps raging (watch the clip with the interview to Daniel Lacalle, discussing possible recovery. Notice that the interview took place before the second wave of the pandemic). The impact is different across regions both because of the severity of the pandemic (and of the countermeasures) and because of the fundamental clock of the economy in a specific region. In the US, as an example, technology is an important clock, whilst in Europe the banking system plays a more significant role, in Asia the regional demand can serve as a throttle regulating consumption and hence recovery.

In Western Europe the banking system has stepped in to provide low cost money to counteract the loss of earning of a big chunk of the working force (this has been done in the US as well but to a much lower extent). The problem with this is a decrease of money availability in the long term (you cannot keep printing fresh money to sustain spending) and the fact that a good portion of that money did not go to sustain production but to sustain access to basic resources (food, rent,...). In other terms, from a productivity standpoint, this is wasted money (that, of course, does not mean that it is not needed!).

The long term impact of the pandemic are still under discussion. The general feeling is that a full economic recover will not be seen till 2024, although a few sectors may see a rebound starting 2021 (actually companies developing vaccine, if successful, are going to see sharp turn over increase early 2021). The need for returning the money that has been printed to sustain the economy distress will decrease the amount available for quite a few years, particularly in Europe. However, on the long term, this Megatrend of capital abundance should prove to be correct.

For sure the pandemic has accelerated (is accelerating) the Digital Transformation and this, in turns, is furthering efficiency in capital movement and management, freeing resources and making it easier to access resources, including capital.

*5. **Augmented Reality and Spatial Web***

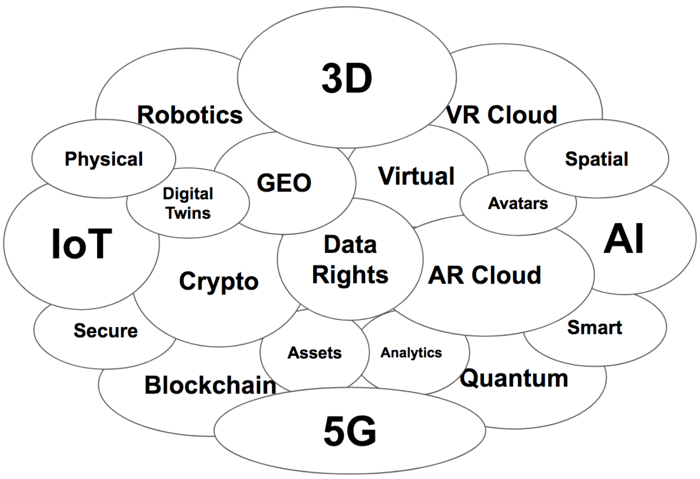


Fig. 14 The [Spatial Web weaves together all of the digital and physical strands of our future world]() into the fabric of a new universe where next-gen computing technologies generate a unified reality. Image credit: Gabriel René, Book The Spatial Web, 2019.

Augmented Reality has been around for several years now. Actually, Virtual Reality came first, the possibility of immersing oneself in a virtual world, but in the last few years the flanking of virtual and real has taken the upper hand in several business and, more recently, consumer applications. Virtual reality goggles have improved but not as much as many believed they would and we are still facing a gap between the "reality" offered by these devices and the one we are experiencing every day with the result that "virtual" remains "virtual" in terms of perception and often creates a sense of uneasiness, even dizziness. One of the reason is that our brain integrates multi-sensorial flows of data and if there is a mismatch (like the movement perceived through your eyes' is not coherent with the data received by proprioceptors -in your ears and joints-) something feels wrong. Although vision goggles have been improving (as an example there are now untethered models and the screen resolution has improved) we haven't been able (with few exceptions like professional flight simulators that re-create movement and acceleration sensations) to re-create the flow of data that would normally occur in real life and this is likely to remain unchanged in this decade.

Fig. 15 Ikea lets you browse their catalogue and "see" how a furniture would fit in your home. In this case how a table would look like in your living room using your smartphone to deliver augmented reality. Image credit: Ikea

On the other hand, seamless overlay of cyberspace data on the physical world does not create the issues we are facing with Virtual Reality. Here it is not about fooling our brain, rather it is adding an extra "sense" to our brain or extending existing sensorial capabilities, like increasing our sight into the infrared spectrum, hearing in the ultra-sound frequencies ... Additionally, devices to extend our sensorial space are, usually. less cumbersome than VR goggles. Actually, we can use our smartphone to access augmented reality!

We can expect to see a growing space for AR application. Industry is already a major user of AR for operation and maintenance, retail applications are growing and, interestingly AR in this areas is seen both as a way to incentivate buyers and as a way to decrease returns of merchandise. This latter is becoming a major hurdle for online retailers. In the UK the cost of returned merchandise has reached 60 B£, 30% of online orders are returned. Products return has been eased and at no cost for the customer, as a way to establish trust and grow sales. However, many customers are now routinely over-ordering as a way of see and touch the merchandise in their home, keeping the one that fits best and returning the others. During the lock down in UK online retailers have seen a 40% increase of intentional returns (those that the customers knew would return at the moment they placed the order). Augmented reality is seen as a technology/service that could significantly decrease this problem.

Other present use of AR can be found in Education, field operation, healthcare, business logistics and more. As an example of using AR in collaboration watch this clip. The growth in AR is fuelled by the Digital Transformation through the creation of data and the connectivity being established between products/products' users and service providers.

This Megatrend foresees a tremendous growth during this decade to the point were AR becomes the normal way to access the cyberspace. The point here is that we will reach a dimension ("digital reality" in the parlance of the Digital Reality Initiative) where cyberspace and physical space overlap in a seamless way. Everything we will perceive as reality will actually be a mixture of bits and atoms. Interestingly this does not restrict to human perception. Also "object" perception will be a mixture of bits and atoms. As Digital Twins move to stage 4 (we are now at stage 3 in most applications) an object will be made up by atoms, local bits (software enabled features) and its digital twin that operates in the cyberspace but is also a fundamental part of the object and its behaviour.

This is sometimes referred to as the "Spatial Web":

a pairing of real and virtual realities, enabled via billions of connected devices, and accessed through the interface of Virtual and Augmented Reality

As shown in figure 14 the Spatial Web results from the seamless integration of different technologies, part in the hardware side (like IoT, robotics), part in software (like AI, clouds) and part in connectivity (like 5G, digital twins, blockchain). By the way, the reason for the name "Spatial" is because the bits will be associated to a location (will become visible and meaningful in a specific location). For more insights watch this clip. A search on the web will return different results depending on where we are since the result will be materialised in the context we are in.

According to Deloitte, the shift towards the Spatial Web has already begun. Whether you feel it today or not, I have no doubt that the dividing line separating the physical from the cyberspace is becoming fuzzier and fuzzier and will completely vanish by the end of this decade.

Of all the Megatrends proposed by Peter Diamandis this is the one that I am most sure of!

*6. **Everything is smart, embedded intelligence***

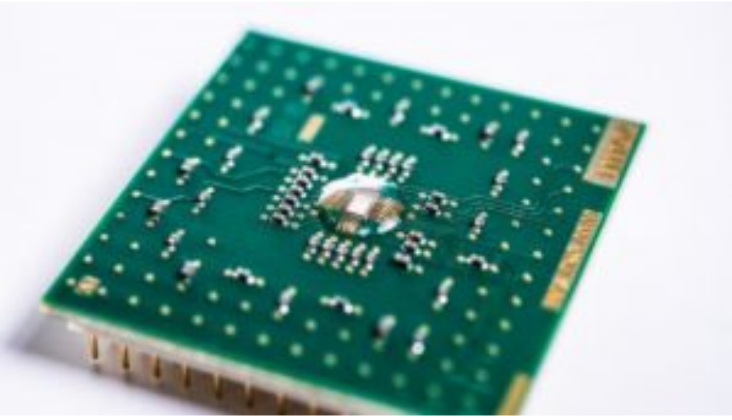


Fig. 16 The chip developed by Imec and Global Foundries using analog techniques for a low power machine learning engine for edge AI. Image credit: Imec

17. The packaging and the shop label claim this is an "intelligent" steak grill. You just place the steak and it would decide how to best cook it! Photos taken by me at Kasanova shop in Turin

This Megatrend may appear "outdated". If you look around with a lay-person's eye you'll see plenty of ads claiming "intelligence" of products, most of the time in a ridiculous way. The first (that I know of) "intelligent" toothbrush debuted at CES 2017, now you can find quite a few intelligent toothbrush on Amazon starting at 24.99$.

On figure 17 a photo I took some time ago in a shop in Turin, selling an "intelligent" steak grill. The box pointed out that the grill was "intelligente", you just place the steak on it and it would decide the cooking temperature and the time needed. I guess it had a sensor to detect the temperature inside the steak and based on your preference (raw, medium or well done) it knew when to stop the grilling. A chip provided the algorithm that I suppose would start with a high temp to broil the surface and them a lower temperature for cooking until the inside of the steak reached a certain, predetermined temperature.

Now this is fine, and probably results in a grill that can cook a steak better than what I would be able to do, but calling it "intelligent" is quite a stretch.

It is just an example out of many you can see for yourself just looking around. Sometimes an object is defined "smart" and this, in a way, it is a prowess restricted to a very specific task, an assertion usually much more appropriate than claiming for intelligence. For sure, we have seen many more products being defined as smart but the words "artificial intelligence" have grown to the point of becoming a ubiquitous presence and we are now seeing variations on the theme.

Gartner in its 2020 emerging technologies hype-cycle identifies :

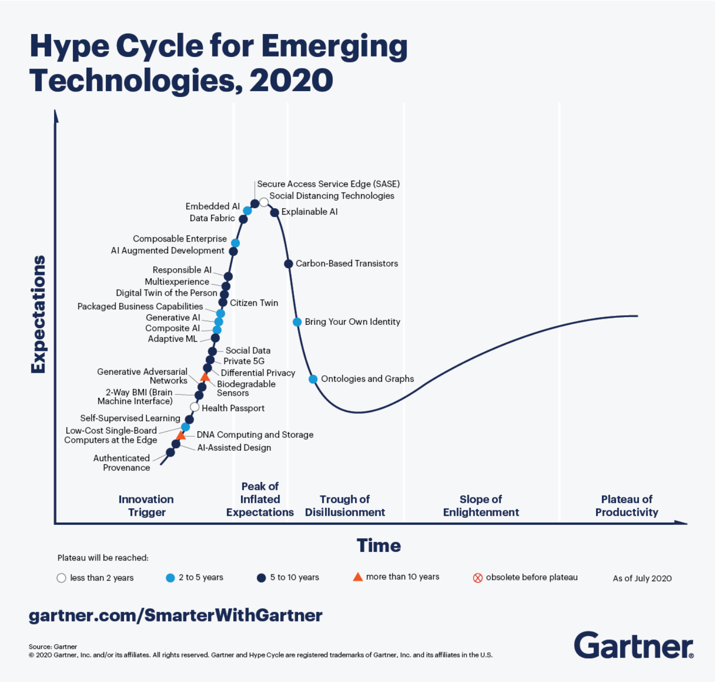


Fig. 18 The Hype Cycle for emerging technologies is out and it is interesting to look at what changed since last year... Image credit: Gartner

- Generative Adversarial Networks (a tech for self-learning by a machine)
- Self-supervised learning
- Adaptive Machine Learning
- Composite Artificial Intelligence
- Responsible Artificial Intelligence
- Generative Artificial Intelligence
- AI augmented development
- Embedded Artificial Intelligence
- Explainable Artificial Intelligence
- AI assisted design

One third of the predicted emerging technologies are in the AI field (10 out of 30).

So, on the one hand we have a pervasive perception of AI presence in our world today, on the other hand we see more and more research on different aspects of AI (as in the Gartner list) that will result in an expansion of capability and of application areas in this decade. There is more.

On November 18th Halide, a company developing software for computational photography, published a review on the iPhone Pro Max 12 photo capabilities.

In that review they discovered an amazing, although hidden feature of this phone. As you may know, the iPhone Pro Max 12 has three lenses, i.e three cameras/three sensors. The wide angle lens/camera has the biggest photo sites (the buckets gathering the incoming photons) 1.7μm versus the 1.4μm of the other two cameras (yes I know 1.7μm may not seem something to call "big" but it is 20% bigger than the others, meaning it can harvest 20% more incoming light and that makes a difference when you are dealing with very low light, as in night time photography.

Here comes the amazing part. When you take a photo in low light condition and select the telephoto camera you'll see, as you would expect, in the iPhone screen the "zoomed in" image. However, the phone will not use the telephoto camera since the software has detected a low light situation and switched to the wide angle camera. Then, in real time it crops the image frame to match the frame size you will get if it was using the telephoto lens. Well, you might say: "this is a trick that really does not require any intelligence!" and you would be right expect that you are not!

When you take a wide angle photo and then a telephoto you get a zoom in effect that can be obtained by cropping the photo taken with the wide angle lens but that cropped image will not be like the one taken by a telephoto lens: the perspective changes (using a tele depth distances are squeezed) and the bokeh is dramatically different so that our eyes (brain) would spot the difference.

Not so with this iPhone. The software (computational photography) will look at the scene, "understand" the image and reshape it to match the result that would have been produced by a telephoto lens. Now, this is what I call "intelligence"! And yet, it is not advertised as such (I guess for marketing reason: Apple might consider better to hide this little cheating, letting you feel that you have control on the selection of the camera...).

Hence we are seeing:

- hype (often just pure hype and no substance),
- ongoing research effort in bettering AI and extending its application, and
- AI becoming a tool in a growing number of industries, both as part of a product and as part of industrial processes, although we may not be perceiving it.

These latter two are obviously the most important and are the ones that are sustaining this Megatrend "everything is smart, embedded intelligence".

A significant evolution that is happening in these last years, and that will be in full swing in this decade, is the capability to embed intelligence (at least a little bit) inside more and more objects leveraging on the evolution of electronics "designed" to support ML.

An example is given in figure 16: a chip developed by Imec and Global Foundries using analog techniques for a low power machine learning engine for edge AI. Here the crucial point (taking for given the lower and lower cost) is the low power demand, allowing its embedding in a variety of products. Notice that the chip on its own would not be enough: it needs to be fed by data and these are provided by embedded sensors -IoT-, an integral part of the Industry 4.0 evolution *AND* it needs to become part of a network of local intelligence leading to an emerging "ambient intelligence".

This latter is what is probably going to characterise the next decade (2030-2039) with 6G playing a major role.

Digital Twins may also play a significant role in this distributed smartness and embedded intelligence, creating a bridge between an object and the cyberspace and (stage IV) contributing to the object functionality (and behaviour). A Digital Twin can embed a local (object) intelligence and can be part of a shared/emerging intelligence (once they move at stage V - cooperative Digital Twins).

6. *AI au pair with Human Intelligence*

Fig. 19 The roadmap for AI to take the pilot seat on commercial airplanes. Full replacement targeted for 2035. Image credit: EASA

1956. This is the official starting point of the race to create an artificial intelligence that could match the human one.

Some 20 mathematicians and scientists brainstormed for 8 weeks to outline a path forward. The hope was to be able to create a machine that would demonstrate a level of intelligence "au pair" with human intelligence.

Overall the mood was optimistic and that optimism pervaded the following 15 years as better and better programs were written. However, after the initial burst of results it seemed that AI work has met a roadblock. New approaches were needed, and AI faded away from mainstream "news". In these 65 years we have seen waves of renewed interest followed by neglect. Each new wave, however, brought forward a bit more clarity on what should be tried out as well as what kind of intelligence should be expected. Even though the goal of an AI au-pair with Human Intelligence, as expressed in this Megatrend, still fascinates imagination, we are now looking at something different.

As a matter of fact, when we say that we want to match human intelligence, the starting point should be an understanding of what "human intelligence" is. And the picture of human intelligence is quite fuzzy!

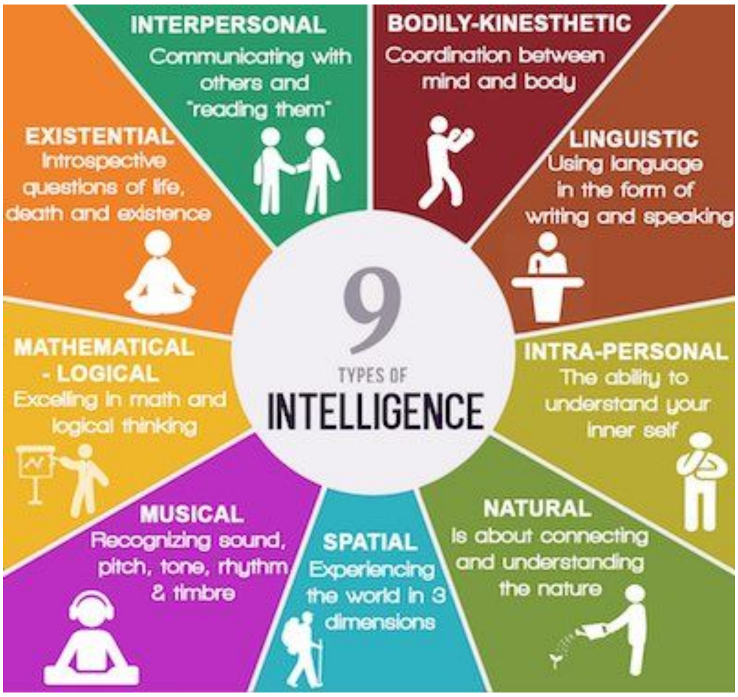


Fig. 20 The 9 types of human intelligence that are usually accepted as classification. Image credit: communicatorzdev

There are several types of human intelligence that have been identified (or classified, since it is not a partitioning that is based on some objective facts). Most experts in the field classify them into 9 types:

- Mathematical/logical
- Spatial
- Interpersonal
- Linguistic
- Interpersonal/social
- Intra-personal
- Natural
- Musical
- Existential

If we look at this list we can easily find types that are fitting a machine (software), like mathematical and logical capabilities, where we have several demonstrations of capabilities to prove theorems (so going beyond pure calculus...). Actually, we have some theorems that have been proven by computers (and some mathematicians refuse to acknowledge the proof!). If you are interested in this area you may like this paper discussing "superhuman mathematics".

Other areas, like "Spatial" involving the perception of 3D space and its implication, are now addressable by machines in a very effective way, although leveraging on very little "intelligence". As an example self-driving cars use a variety of sensors (LIDAR and image sensors) and a lot of number crunching to create a 3D model of the surrounding ambient, that use some form of AI to make sense of data (like identifying objects and then deriving the probability of behaviour -a pole is unlikely to cross the road, not so for a stroller that may be pushed from the sidewalk to the right lane as the car is approaching, although unlikely, whereas higher risk exists for a kid chasing a ball). This sort of "machine intelligence" does not exactly map onto human spatial intelligence that includes characteristics like orientation, something difficult for us (in principle - imagine being stranded in the middle of nowhere...) but quite straightforward for a machine having access to a GPS.

Other areas, like "Musical or Linguistics" have been considered "out of reach" for machines, but we have seen in these last few years examples of machines (software) that can create "music", paintings and poetry to a level that can fool people (including experts). The difference with people, of course, is that a composer would enjoy what is doing and be proud of the result, sensations that are not present in a machine (as far as we can tell).

Other areas, like "Social Intelligence" would seem to be far from a machine. However, we have seen significant progress in social robotics that ends up in machines that can establish an empathic relation with people. Again, a machine has been programmed, or has been programmed to learn, to be empathic, it doesn't feel empathy.

For sure the areas of "intra-personal" and Existential" intelligence do not make sense for a machine (at least so far, unless you are interested in science fiction).

So what is this Megatrend about? It is not about the essence of Intelligence (assuming we can reach an agreement in defining what it is), it is about "performance". If a machine can perform as well as a human being in a broad variety of contexts and situations that would require "being smart", thus allowing the replacement of a human with a machine, than we can say that AI is "au pair" with human intelligence, like:

- can we replace a poker partner with AI?
- can we replace a pilot with AI?
- can we replace a medical doctor with AI?
- can we replace a financial advisor with AI?
- can we replace a teacher with AI?
- can we replace a journalist with AI?
- can we replace a discussant with AI?
- ...

The list can go on and on. If you like to explore a bit more, click on the links and you'll see what it is already possible today in using AI to replace people.

However, here the crucial point may seem to be in the words: "a broad variety of contexts and situations". All the above examples, and many more, seems to point to the fact that we have, today, the capability to replace a person with AI in a specific domain. It may not be done in practice, because of cost or because of some shortcomings, but it is obvious that in the near future the cost will go down and many of the shortcomings will be overcome. So we can say that performance achieved in a specific sector is not a proof of having reached a human like intelligence, only that we are able to develop expert systems in that domain.

Actually, this is not a satisfactory objections. Computer software is additive and can scale graciously (at a cost, of course). In other words if you have an AI system able to impersonate a pilot, you can extend that (if you want to) to impersonate a musician by adding the required software (or asking the self-learning engine to dedicate a day to become a proficient musician). Provided sufficient computer power (either centralised or distributed) and having AI software capable of delivering intelligence in a given sector you can pick up that capability and add it to another set of capabilities.

This Megatrend is not about a philosophical discussion on the equality of machine and human intelligence, it is about the availability, by the end of this decade of an artificial intelligence able to perform as well as humans in a broad variety of fields. It is not suggesting that an AI creating music will "enjoy" the piece it has created, nor that an AI pilot will feel proud after a particularly tricky landing, just that AI did the job.

Taking into account that we are now moving towards open AI, that is the possibility to access AI functionality from any object, thus spreading out the intelligence in any ambient and, conversely, to have any object contributing to an emerging AI (by harvesting / sharing data and creating local intelligence) I am pretty confident that this Megatrend is a concrete possibility that will be implemented, step by step, over the coming years.

7. *The coming age of AI-Human collaboration*

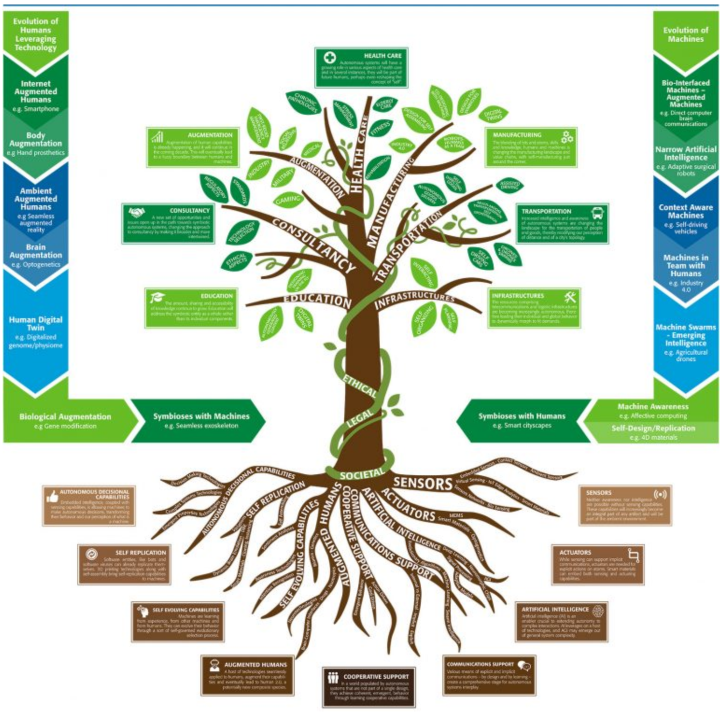


Fig. 21. The expected convergence of the evolution of machines (right hand side) and human (left hand side) augmentation. The augmentation is fuelled by the set of technology areas depicted as roots of the tree, whilst the leaves indicate application areas.

Fig. 22 AI as a Service -AIaaS- is expected to grow in the next few years at a CAGR of 48%, reaching a market value of 15+B$ by 2023, with the lion's share taken by the US. Image credit: TechNavio

This Megatrend is already affecting our life in many ways as well as affecting business. Think about talking to Alexa or Siri: you are actually bringing AI into your everyday life. Pick up your phone and take a picture: AI is at work when you click to determine the correct exposure given that type of image, detecting a smile on a face... Are you turning for help to Google translator to help that Japanese tourist that has asked you a question? That's again AI at work.

In a factory plan robots are starting to interact with blue-collars and AI is supporting the interaction and collaboration. Are you on the trading floor of a stock exchange? You are most likely to use AI to support your decisions. Are you a doctor looking at a CAT and reading the report? Most likely AI had a lot to do in that report content.

What we see today (and most of the time not perceive) is just the harbinger of what is coming in the next few years. By the end of this decade (and this is what this Megatrend is all about) AI will be an omnipresent companion. We have seen the starting of the market of AI on demand, AIaaS - AI as a Service - see figure 22, and we have seen the announcement by Google to offer access to an AI Cloud through public API - Application Programming Interface- that turns AI into - basically- an infrastructure that can be used everywhere and in any type of application.

A similar offer is available through Amazon AWS. Amazon Polly offers up to

5 million characters text to speech capabilities per month (that is over 1,500 pages of text translated into voice); Amazon SageMaker offers 250 hours per month of processing capacity to train AI models; Amazon Lex allows you to create Chatbots and having them processing 10,000 text requests or 5,000 voice request per month; Amazon Rekognition supports the analyses of 5,000 pictures and store of 1,000 face metadata per month; Amazon Comprehend lets you develop natural language understanding of up to 50,000 phrases per month and Amazon Transcribe lets you add speech to text capabilities to your application for up to 60 minutes per month: all of this for FREE! Amazing.

Notice that particularly in some areas where training is needed to create AI the process is very computationally intensive and only the big ones, with their huge computation capabilities can support this (hence the value to be able to access services like Amazon SageMaker). Having access to these resources is going to multiply the development of AI and widen its areas of application.

At the Symbiotic Autonomous Systems Initiative (now Digital Reality Initiative) we came up with a roadmap leading to a symbiotic relation among humans and machines (see figure 21) foreseeing a parallel evolution of capabilities in machines (getting more and more smarter) and in humans (getting more and more seamlessly connected with machines) that is leading, by the end of this decade, to a symbiotic life, where we, humans, will leverage seamlessly from the augmentation that machines can provide (better sensing, faster processing, specific augmentation in some areas of intelligence) and at the same time machines that will be leveraging on our intelligence in a shared environment. For an in-depth discussion on these topics you can take a look at the eBook "**Augmented Machines and Augmented Humans Converging on Transhumanism**".

Fig. 23 Baxter, the collaborative robot, is shaking hands with a little kid. It has been designed to work along with humans and to learn from them. Image credit: Rethinking Robotics

Collaborative robots -cobots-, like Baxter (no longer in production but it marked the starting point of a human-robot collaboration), are already a well defined area of research and more importantly are becoming industrial products.

What is interesting is that these collaborative robots were designed to be safe when operating in teams with humans. Then they evolved, through AI - machine learning -, to become capable of "learning" from their interaction with humans, and, further step, to take the lead, when needed, and teach human coworkers so that the teamwork can become more and more effective.

8. *Living in a software "cocoon"*

Some of us have already achieved a familiarity with AI assistants, like Alexa, GoogleHome or Apple HomePod. The obvious evolution is towards an increased smartness of these assistants and, in turns, this will be leading to a "personalisation" of the interactions. Think about it: as you talk with the assistant in your home the assistant will know more and more about you, it will remember what you asked yesterday and it will start guessing what you are really interested in, anticipating your needs. Progress in emotion detection (and affective computing, see figure 23) will enable an "understanding" of your emotional status that in turns will provide the assistant with clues on what you need. It will become a real "personal assistant". Of course, a home assistant can be able to

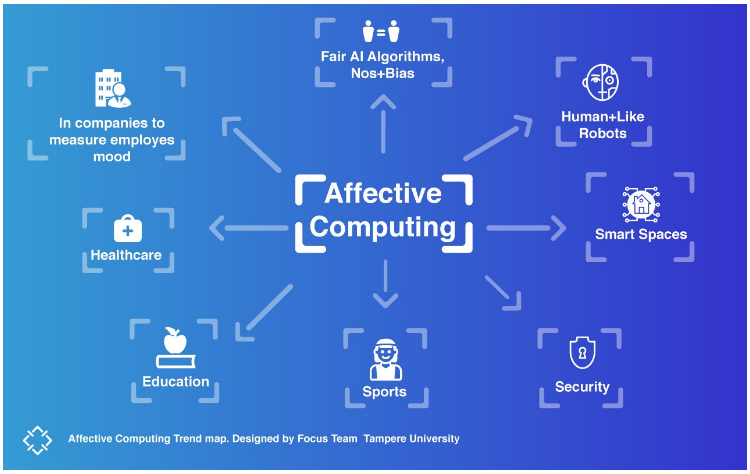


Fig. 23 Affective computing is a relatively new area mixing sociology, psychology, IoT, AI and computer science to create systems (software) that can become aware of emotions and interact with human beings taking their emotions into account. It can be applied, as shown in the graphic, in many areas, including personal assistant (smart spaces). Image credit: Valentina Ramírez

double, triple up, becoming a personal assistant to each of the home dwellers...

Now let's take a step forward. Why not take that "personal" home assistant along with you, through the day?

This is basically what this Megatrend is all about: the creation of cognitive prosthetics that will become commonplace by the end of this decade, augmenting people's intelligence (at least that kind of intelligence based on information and decision making through information processing).

The growing work on Digital Twins, particularly the one carried out in academia and research environment (that is extending to people the concept of Digital Twin now widely adopted by industry to create a copy of a physical object and even by cities to create a copy of cities' processes and infrastructures) is contributing to this Megatrend. So is the work carried out in the Knowledge as a Service, part of the Digital Reality Initiative, aiming at creating Cognitive Digital Twins to capture the knowledge of a person or an organisation.

By the end of this decade it is reasonable to expect our life will be lived in a context that is no longer just made of the physical entities around us, rather it will be a context resulting by the overlapping of the cyberspace on the physical space we are living in.

This assertion, supported by the evolution of technology that provides a seamless connection of physical and virtual (like IoT, ambient awareness, AI, VR and AR), is actually much trickier than it might seem at first glance.

One of the tricky points is related to the presence, and mediation, of personal assistants/Personal Digital Twins. Think about it: today as we talk with one another sipping a coffee, we are in the *same* physical context. We might have slightly different interpretation of this context, like it might be perfectly ok for you whilst I find this ambient pretty noisy and uncomfortable but it is not that difficult to agree on the perceived reality. On the other hand, in a Digital Reality situation, my perceived reality depends on the perception of the physical space (similar to yours) compounded by the perception of the virtual space provided by my Personal Digital Twin that will differ from the one provided by your Personal Digital Twin. The problem arises from the seamless perception of those two "realities" as a single "true" reality. As we lose the separation between the two it will be more and more difficult to compare my perceived reality with yours!

Yes, in the next few years we will probably access the virtual part of reality, that one contained in the cyberspace and mediated by the Personal Digital Twin, through a device, like AR glasses so that in case of mismatch we can just remove the glasses and go back to the physical context. However, in the longer term, the Personal Assistant might become an extension of our senses, embedded in our body, may be in the form of an electronic contact lens and aural stimulation. At that point it might be much more difficult to separate the two.

It looks like science fiction but it is already on industry's roadmaps.
If you are puzzled by this, take a step back: look at how much influence television and more recently social media have on people. Depending on the type of information you are exposed, your mindset evolves in specific directions and your way of perceiving the world diverges from the one of people exposed to different sets of information stimuli. The shift towards Digital Reality will just aggravate the social issues that we are already experiencing today in our exposure to artefacts, like television and social media. It will multiply the effect, since it will be shaping our context continuously.

*9. **Globally abundant, cheap renewable energy***

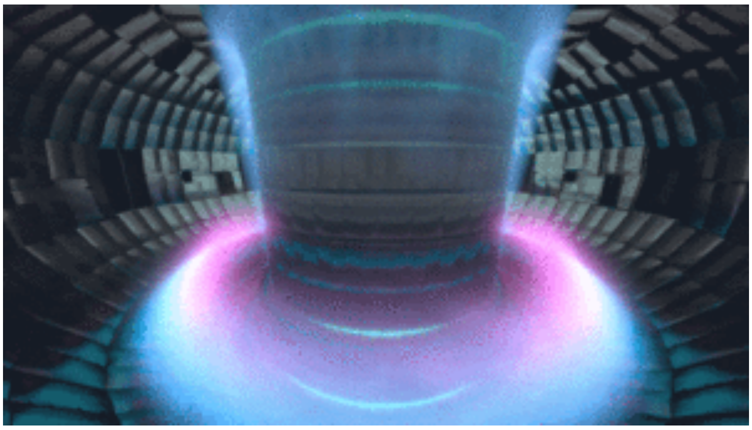


Fig. 24 Rendering of a fusion reactor where the hydrogen is heated until it becomes a cloud-like ionized plasma. Credit: ITER

The use of energy has been a trademark of humankind, from the taming of the fire to the invention of ways to harvest hydropower and wind-power (mills). Yet, for most part of human history the amount of energy used has been negligible.

The industrial revolution can be considered as the dividing line in the harvest and use of energy. There is not a single date for it, it is spread out in the XVIII and XIX century. Coal was the first energy source and the first steam machines were used in coal mines: the very low efficiency of those first engines was not a big issue in places were coal was cheap! For a captivating history of humankind use of energy you can look here.

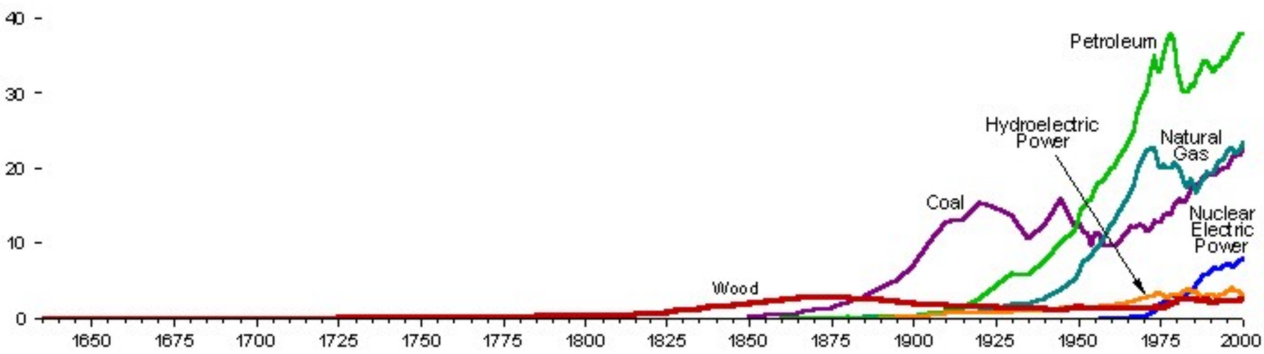


Fig 25. The use of energy in the US over the last 5 centuries. Notice how flat the use has remained till the industrial revolution and the sharp increase in the last century. Image credit: Arlene Courtney

As there is not a single date for the uptake of energy use, so the usage of energy has been, and still is to a significant extent, quite different in different geographical areas (countries).

Looking at energy usage is important from the point of view of wellbeing (measured in pro-capita GDP: yes it does not necessarily correlate with happiness, but it is a fairly good indicator of access to education, healthcare, food and so on) and data show a clear correlation between energy availability and GDP, as shown in figure 26 [created by the European Environment Agency](). As shown, the relation falls (almost) onto a straight line indicating a linear correlation: the more energy is used the higher the GDP.

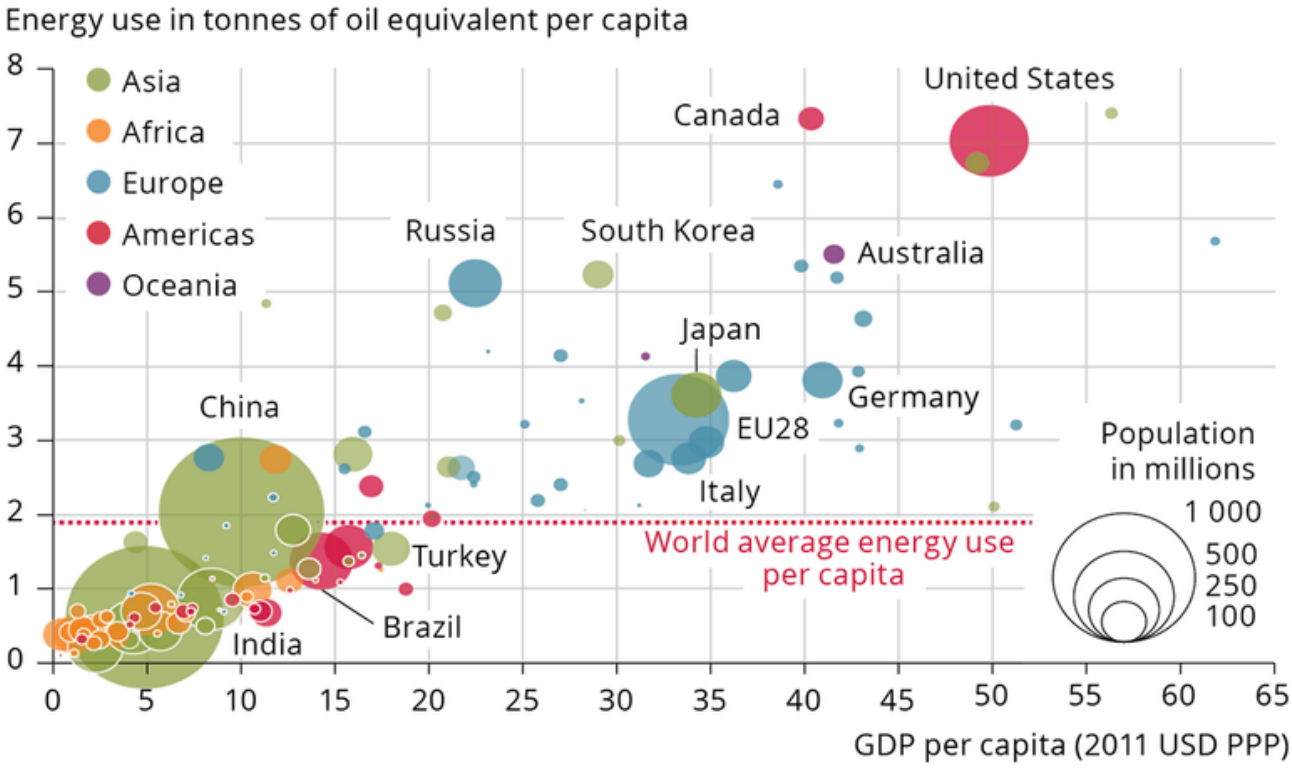


Fig. 26 Representation of energy use (expressed in tons of oil equivalent per capita) versus the GDP per capita. The graphic is based on 2011 data, so quite a bit has changed in these last 10 years but the point made is still valid: more energy use relates to more GDP.
Image credit: European Environment Agency

Notice in the graphics the "bubbles", circles, represent the size of the population in a given Country - India and China having, obviously, bigger circles (the tiny dot at the top of pro-capita energy use is Saudi Arabia).

Of course, access to energy is a matter of availability and affordability (the two are related). Hence, any progress towards more abundant and more affordable energy would result in an increase of the GDP and a parallel increase of wellbeing (again with the caveat expressed above and noticing that distribution of GDP may be quite uneven, although it is generally true that a significant increase of GDP results in a generalised increase for all that Country's citizens).

This Megatrend is about the forecast of an abundant energy at a low cost, available everywhere and based on renewable energy. This latter has been the focus of research for many years and we already have plenty of renewable energy from a variety of sources, hydro, solar, geothermal. The main issues are about continuity of energy availability (solar is only good as far as the Sun is shining, wind powered turbines need the wind to blow...) and its cost. This Megatrend envisages ubiquitous availability at a cost of 0.01$ (1 cent) per kilowatt hour by the end of this decade.

As a matter of fact, what would have seemed wishful thinking just ten years ago is now within reach.

Figure 27 shows the amazing decline in the cost of solar power over the last ten years, a decrease that was previously foreseen to happen over 30 to 40 years. It should be noticed, however, that this

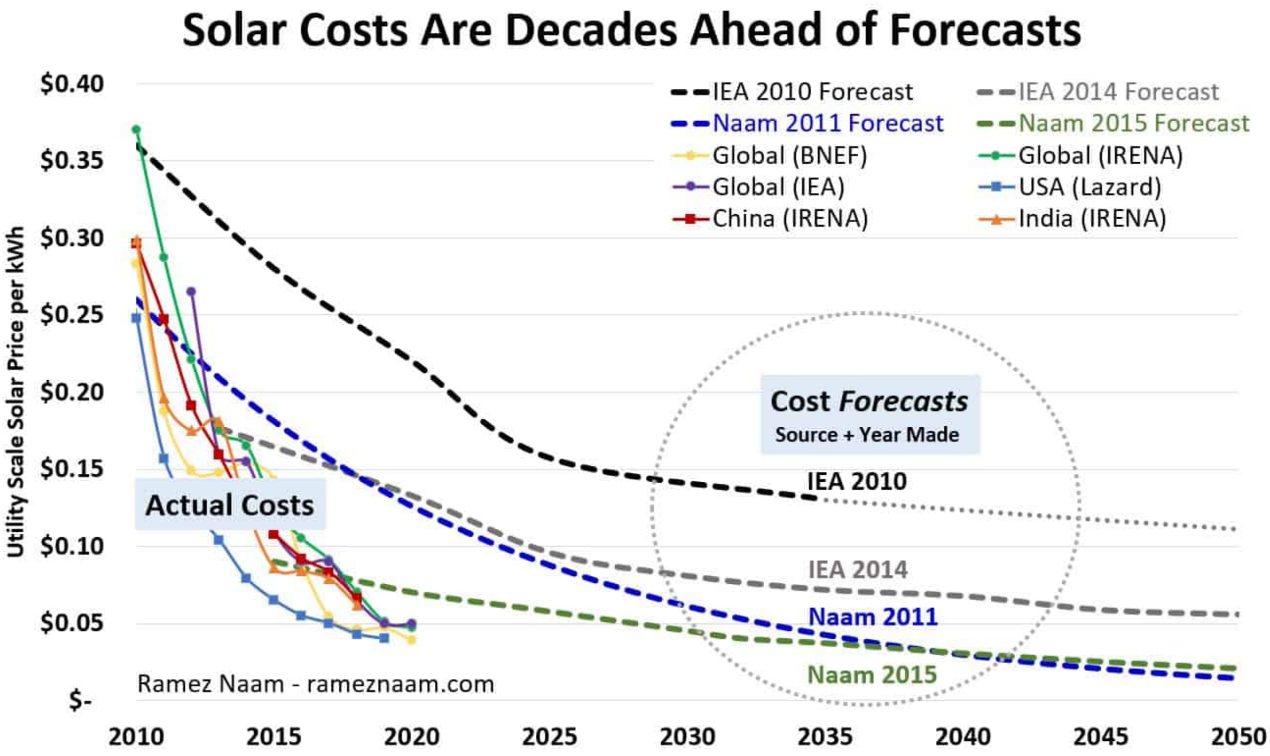


Fig. 27 The cost of solar power, measured in $ per kWh, has decreased much more in the last 5 years than it was expected, reaching values that were expected to be reached in 2040/2050. Image credit: Ramez Naam

amazing decrease applies only to those areas that are enjoying plenty of sun, most of the time of the year.

This trend is in synch with the forecast of this Megatrend to have a kilowatt hour cost in the range of 0.01 $ by the end of this decade.

Also notice that to meet this Megatrend prediction we need a variety of energy sources, solar is not enough. The reason is not that we are lacking solar energy (most of the energy we harvest on Earth is originated by the Sun) rather in the fact that there are only as many places that are suitable to harvest solar energy. Placing photovoltaic panels in the Sahara desert (an ideal place from the point of view of sunlight) would not do: the cost of transporting that energy to the point where it is used would be to high (evolution in superconductivity may eventually change the landscape, but so far it is a no go).

By the end of this decade the exploitation of fusion power should be within reach (if not by the end of this decade shortly thereafter). The ITER program is now involving over 60 Countries and the expectation is to have a functioning fusion reactor able to support large scale production of power in the next decade.

It will take few more years before fusion power will progress from feasibility to affordability but the path is clear.

By the end of this decade I am not expecting that we will be able to get one kWh at just 1 cent, that would be some 25 times cheaper than today, in particular that such low cost energy will become ubiquitous. However, I do believe that the price will keep going down and that the shift towards renewable will continue. This will also require availability of cost-effective batteries and that is also an evolution that we might expect by the end of this decade. Notice that as battery use increases the issue of recycling them becomes more and more pressing.

*10. **Insurance: from "recovery after risk" to "prevention of risk"***

Today we insure our home, our car ... ourselves from accidents and insurers evaluate the risk that such accident may happen. To do that they are using statistics and more and more try to customise the risk evaluation to be as accurate as possible. It makes sense, of course.

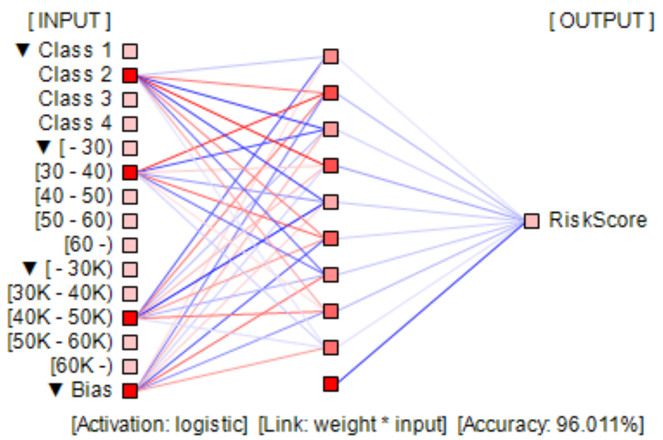


Fig. 28 The use of Artificial Intelligence is growing in the Insurance domain to provide better accuracy on risk's estimate. Image credit: Rosella Machine Intelligence and Data Mining

However, technology evolution -read IoT/Internet of Things, pervasive communications and massive amount of data- makes possible to use this prediction of risk to ... avoid it.

Hence, why not pay for a service that is actually aiming at reducing my risk? Think about having sensors at home that can detect any increase in temperature, a tiny whirl of smoke and some actuators that can sprinkle the area to extinguish an incipient fire, or car sensors that can step in to avoid a collision or immediately report a theft attempt sending a drone to record the thieves (and possibly scaring them to the point of giving up). Think about having a virtual doctor monitoring your vitals and stepping in, in case of a red flag.

We are already starting to see these kinds of services, today provided by specific companies. In the future, however, it makes sense to imagine them provided by insurance companies as integral part of the package. It is usually way cheaper to be proactive rather than stepping in once the damage has been done. This is a very strong incentive to insurance companies to take advantage of new technologies and move into the area of risk prevention!

Artificial intelligence coupled with sensors will be able to create awareness, evaluate risk in real time and activate contrasting actions to decrease it (at the very minimum to decrease the damage). Gone will be the time of a statistical evaluation of risk, much more important is the detection of risk here and now and the implementation of avoidance measures.

This is basically what this Megatrend is all about. It is important because it fosters a change of paradigm. It is not a given that present insurance companies will move into this new setting: it might be difficult for companies that have been growing on a lay back approach (see what happened, take notice to calculate future insurance premium, delay payment as much as possible and thrive on the capital you keep harvesting... may be some insurers will object to my feeling, but I can tell you it is rooted in experience) to take a lean forward approach, interact with the customers' lives and assets and provide guidance/step in with actions in real time. Insurers don't have organisations nor systems designed for real time action.

This is why I tend to favour a scenario where companies that are today providing real time support/monitoring will be in a better position to become the insurers of tomorrow. There will be exceptions, of course, but if I have to bet, I would bet on a fading away of current insurers and the rise of new players.

*11. **Autonomous vehicles and flying cars***

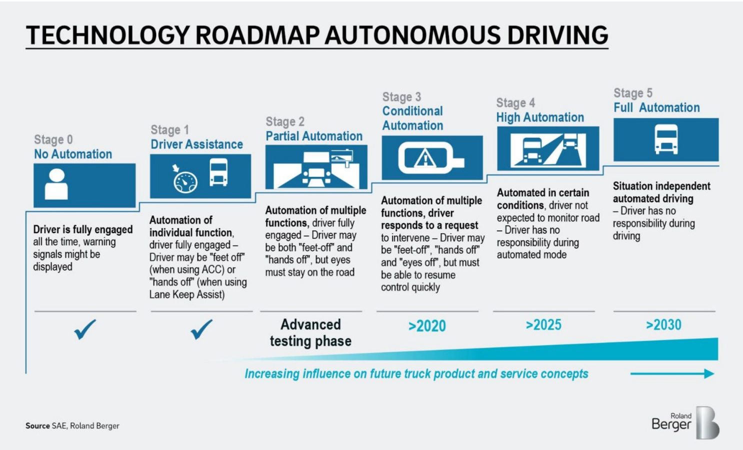


Fig. 29 Roadmap for autonomous vehicles. Full autonomous vehicles are not expected to became the "norm" in this decade. We shall wait for the next one and possibly till 2040 they will not take the upper hand. Image credit: SAE - Roland Berger

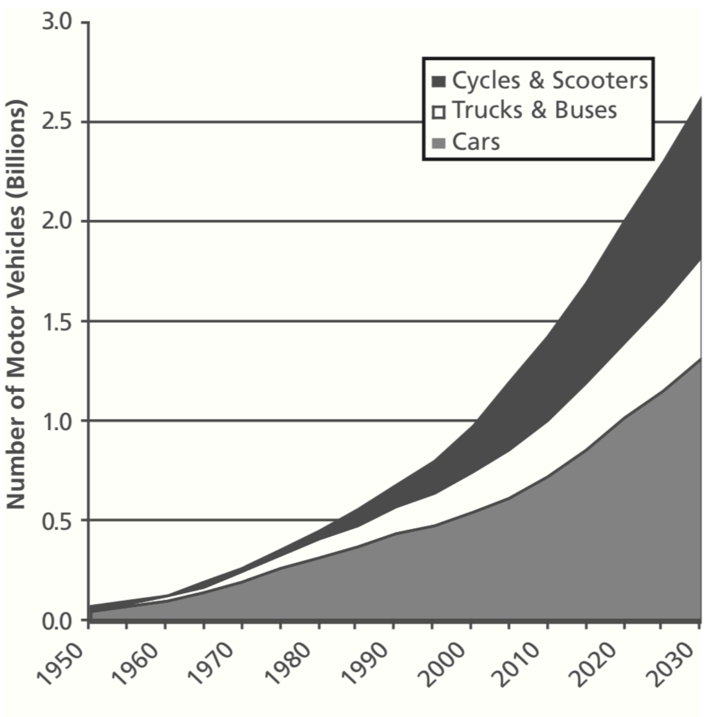


Fig. 30 Graphic representing the growth of vehicles, cars, trucks and motorcycles, in the last 70 years with projection up to 2030. Notice that the growth in this decade is fuelled by developing countries whilst the market in developed countries is flat or declining. Image credit: Sperling, D., and D. Gordon, Oxford Press

There are already a number of autonomous vehicles, both self-driving cars and autonomous trucks. Additionally, there are several fully autonomous drones and a few airplanes flying in the sky.

However, if we compare those numbers with the numbers of vehicles/planes we can see that the former fall in the curiosity domain. There are an estimated 1.4 billion cars in the world (in case you wonder, since 2017 China is the number one with 300+ million cars, having surpassed the US).

As shown in figure 30, the number of vehicles is almost twice as much the number of cars, if you take into account motorcycles and trucks.

We have already seen an autonomous motorcycle, courtesy of BMW, but the point there was to show the progress of technology (and expertise) rather than paving the way to a real product.

If we look at flying objects we have autonomous drones (in the military but now also becoming available for commercial applications, like inspection of infrastructures). Very recently Garmin got approval for its devices to self-land planes.

All of the above is telling us that the technology to create autonomous vehicles is available. So the real question when looking at this Megatrend is what stands in the way between technology and its exploitation.

The biggest hurdles are regulatory. Of course, it is not about tardy regulators not doing their job and adopting/accepting technology evolution. It is about the principle of caution: before approving something be double sure that there are no (hidden) issues. If a self-driving car has an accident it makes newspapers headlines. The few thousands autonomous cars driving around today have had very few accidents, the fatal ones can be counted on a single hand. On the other hand, 3,700 fatalities from car crashes occur every day, a staggering total of [1.35 million people die every year]and an additional 20-50 million suffers from non fatal injuries.

However, we need to factor in the "billion" of normal vehicles on the road, a million times more than self-driving cars. According to Tesla statistics (and their interpretation) Tesla cars are safer when in autonomous drive mode than when driven by a human driver but it remains to be seen what may happen as more and more autonomous vehicles hit the road. Are they really safer or is the current statistics biased by the fact that many drivers are actually finding this type of vehicles more predictable, hence contribute to avoid accidents? The questions on the table are many and this explains the reservation of regulators.

Over this decade it is obvious that more data (and more autonomous vehicles, foreseen to reach 10 millions in the next decade) will become available. That will provide both better interpretation of statistics and allow autonomous vehicles manufacturers to fine tune them for increased safety.

In parallel we will be seeing progress in technology (sensors, AI in particular) and lower cost that in turns will make possible to increase the functionality (and safety) and increase the market demand.

What is most interesting in discussing this Megatrend is that the path forward consists of many little steps, both in terms of fields of application and in terms of growing autonomy. Looking at them provides us with information on the evolution roadmap.

In terms of application (in order of deployment):

- autonomous industrial vehicles (inside a factory/warehouse)
- autonomous taxis
- autonomous trucks
- autonomous ships
- autonomous cars

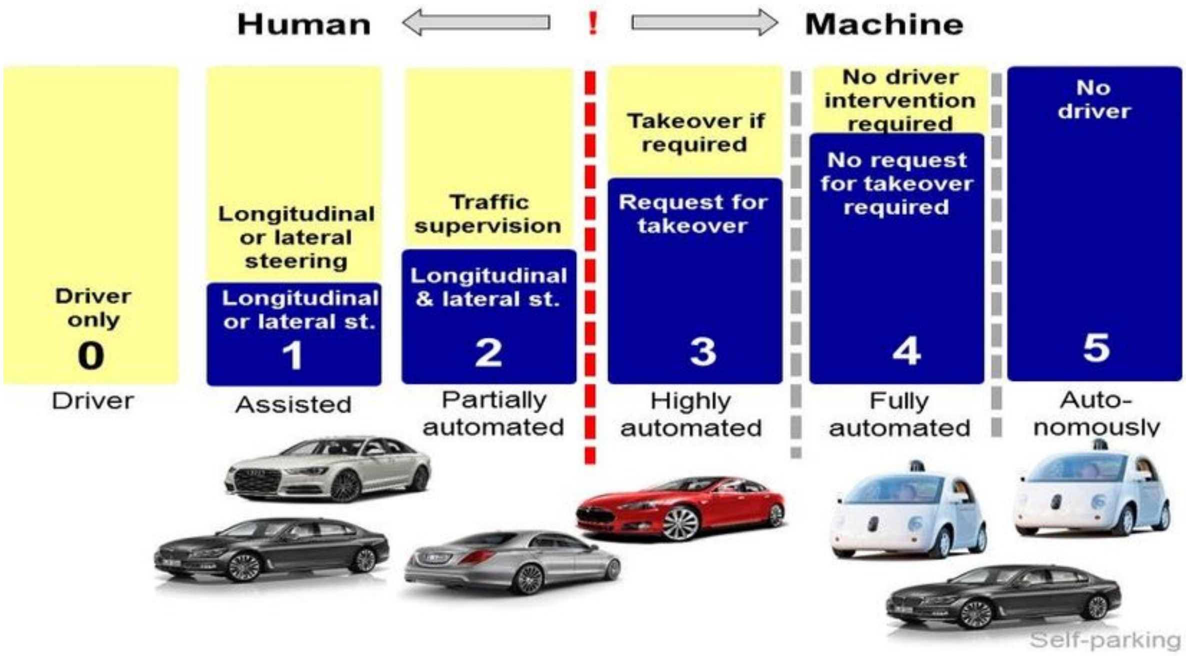


Fig. 31 Levels of autonomous driving according to SAE J3016. Image posted by Mario Hirz

Autonomy is progressing every day. New cars are offering advancement in features:

- detection of obstacles during parking (many cars have it)
- detection of obstacles that might create an hazard during drive (approaching a car travelling at a lower speed)
- automatic braking when an accident is foreseen
- cruise control and automatic braking to slow down
- autonomous parallel parking
- autonomous vertical parking
- autonomous parking without the driver on the car and pick up of the driver after a parking (autonomous valet parking)
- autonomous driving with control hand-over in case of problems
- autonomous driving on highways
- autonomous driving in traffic jams, queue

As you can see from this list it is a sequence of tiny steps that require on the one hand better awareness on the car side and generate increased trust on the "human" side. Likewise on the flying vehicle side:

- autonomous hover
- autonomous navigation and return to base
- autonomous landing
- autonomous obstacle avoidance
- autonomous tracking (of a person, of a face, of an object)

There are now a few prototypes that are close to commercialisation (watch the clip) and it is reasonable to expect that by the end of this decade flying cars will be part of the landscape. Here, again, regulatory issues are a stumbling block. There is a need for a control infrastructure and it is well understood that the one in place today for controlling commercial aircraft does not scale to manage thousands of flying objects in a city (today's aircrafts management involve vertical and horizontal separation that simply cannot be applied in a urban situation of flying cars (with present rules you could have just a few, 3/4 cars flying over a city in order to maintain separation). We will need to move to an autonomous flight control with each flying car coordinating with those in proximity for right of way. 5G and even more so 6G will be crucial to ensure communications.

Fig. 32 Dubai has started to test autonomous flying taxis, and it is expecting to have them in service by 2021. Image credit: BBC

Flying cars are seen as a way to reduce congestion in megalopolis and, as well, as a way to save on fuel (a flying car uses some 15% more power than a rolling car but by flying over shorter distance and not having to stop on the way it ends up consuming less power).

We should also note that flying car were among the "forecast" already 50 years ago (I remember newspapers predicting them as a side effect of the emotional state we had seeing men landing on the Moon) and yet nothing happened in these 50 years. However, technology is now mature and it is reasonable to expect by the end of this decade quite a few of them, starting with cities like Dubai where a desert is conveniently available to support flying over an empty space, thus avoiding safety issues for those walking below…

*12. **Instant economy of Things***

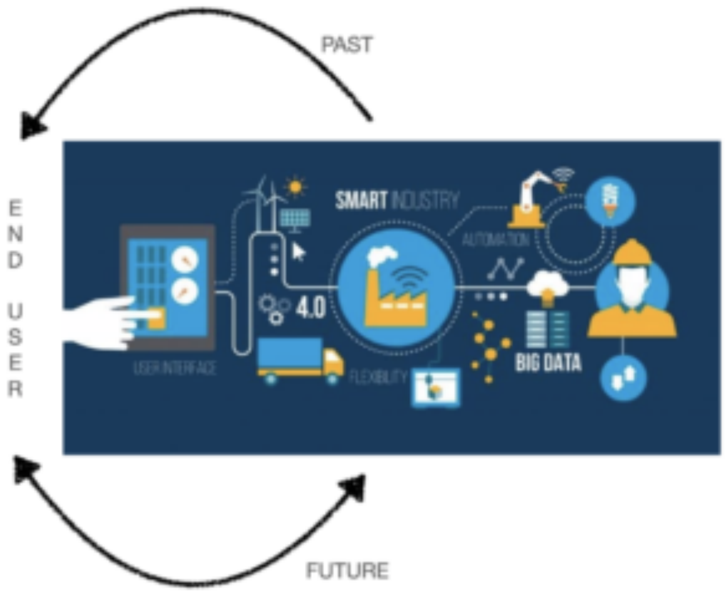


Fig. 33 Up to now, with very few exceptions, the factory produced a product and the end user bought it. In the future we will experience a much higher level of customisation and in several instances the factory will produce "on-demand" and based on the end user specification. Image credit: modified image from Proto3000.com

The great change brought by the Industrial Revolution was the production of goods for an unknown customer. Think about it. Before the industrial revolution production was handled by artisans and they worked on demand. Their wares were manufactured based on customer's specification, be that a piece of furniture, a sword or a cart. The Industrial Revolution changed the paradigm and changed the overall business landscape.

It was the Industrial Revolution that "invented" marketing, since it needed to push product produced "in absence" of a specific demand to the market, stimulating people to buy them!

We take all this for granted, since we have lived all our life in an economic framework where goods are on a shelf and we have the possibility to choose one among them and that's it. Ford mentioned in his biography having said to his sales dealers:

"*Any customer can have a car painted any colour that he wants so long as it is black*."

However, market competition and flexibility in production have created an enormous variety of products offering us an amazing choice, something that was unthinkable 100 years ago. Yet the paradigm is the same as it was in the XVIII century: the factory manufactures products that go on a shelf where customers may decide to buy them. Over the last decades, however, the variety of choices and the preference of the market have sent clear signals to producers: if customers prefer a certain shape/function the industry takes note and starts investing more on that, leading to products that are more and more in synch with the market (differentiation and fine tuning go hand in hand in mass market production).

More than that. In this last decade we have start seeing the first signs of a paradigm shift, taking us back to the pre-industrial era, but still preserving all the advantages of the industrial revolution (abundance, low cost):

- we may create our own photo book and have it delivered to our home n a matter of days

Fig. 34 The Ford model T. The first batch came in black colour only. This was a way to create economy of scale and keep the cost down (hence the price down to reach a broader market). Image credit: Ford

• we can customise our next PC by selecting the types of chip, the RAM, the storage, the interfaces, the keyboard... and have it assembled on-demand

• we can customise our new car by choosing among such a number of "optionals" that our car might turn out to be unique, manufactured just for us

These are just a few examples of a paradigm shift, as shown in figure 33. We are moving from being a "buyer" to becoming a "builder". Of course, it is way easier to be a buyer (all you need is money) than a builder. However, technology is progressing at an amazing pace.
Think about creating an app.

Writing software used to be a very specialised form of technical art (it still is) but now there are tools that can make life pretty simple. I am just using one right now to write this ebook. There is a huge software that is supporting me, although I may not appreciate it. What has been done in these last ten years on production of software will likely happen in this decade (and the following ones) to hard products.

This is what this Megatrend is all about: on demand production and on demand delivery. Initiatives like EIT Manufacturing (watch the clip) are paving the way towards this paradigm shift.

Industry 4.0 is a big part of it but there is more:

- design of raw material
- design through Digital Twins
- on-demand production
- servitization
- instant delivery
- build/customise as you use
- recycling/circular economy

a) *Design of raw material*

Humankind discovered the first alloy long, long time ago. Historians place the date somewhere between 5,000 and 6,000 years ago. In the current Iran/India area our ancestors were using copper and discovered that smelting certain copper ore, like Olivenite and Tennantite resulted in a stronger metal. Some went further and discovered that smelting copper adding a pinch of arsenic led to the same result. Indeed, those ores contained arsenic mixed with copper. That was, based on historical records, the first alloy: bronze (arsenical bronze). Over the centuries it was discovered that mixing copper during the smelting with other substances led to even better result and didn't provoke poisoning of the smelters (you don't want to breath/ingest arsenic). Better results were achieved by mixing tin, in a percentage around 10 to 12.5%. It took 2 millennia to get the right recipe for

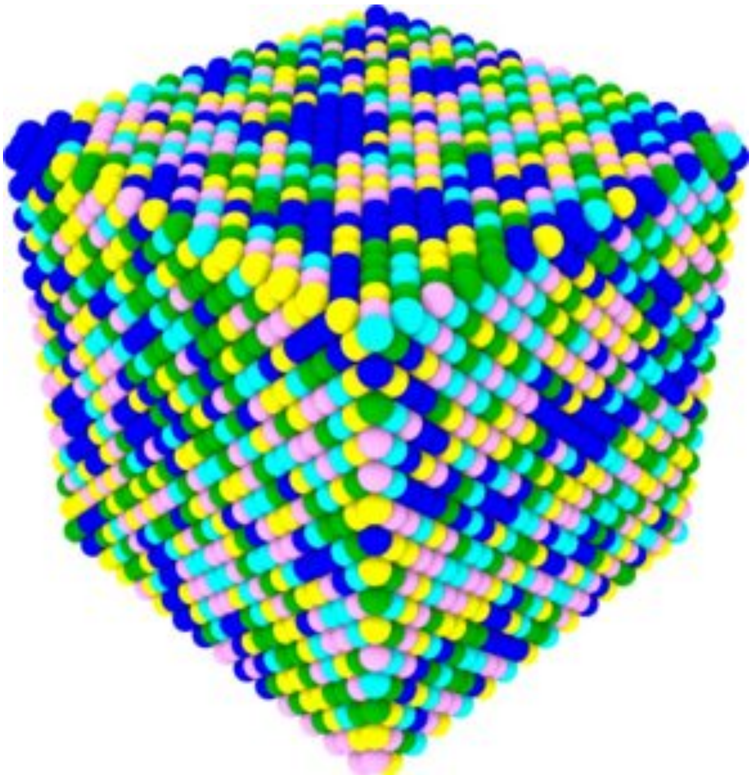


Fig. 35 Schematic illustration of the new palladium-containing high entropy alloy shows how new alloy contains large palladium clusters (blue atoms). Credit: Ting Zhu

bronze and it is still good today (for casting bells).

Over the centuries humankind learned to create several other alloys; the most important one, that fuelled the Industrial Revolution, was "steel". The British found the good recipe for steel and were able to guard the secret for a few decades, then France and Germany (this latter was able to "invent" the recipe by themselves, the French found it more convenient to use spies and attract knowledge ...).

There are a basically unlimited number of alloys, just waiting to be discovered. The problem is that there are "potentially" so many. Researchers are so much interested in alloys because each one has specific characteristics (see in the chart on the side differences for different types of steel).

Their discovery has accelerated in the last two centuries and we have now thousands of alloys fitting different needs (racing cars would not perform as they do without the progress in the alloy department, leading to lighter material, yet with much greater strength).

The quest for new alloys is not over, quite the contrary. In this Megatrend new ways of exploring the "virtual" world of alloys play a major role.

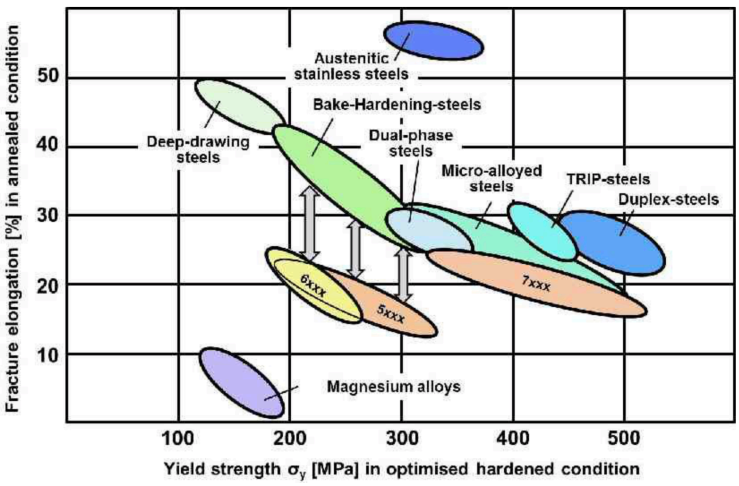


Fig. 36 Different characteristics of steel alloys. Image credit: Dierk Raabe

The word "virtual" is used for a reason. We know that an alloy is the combination of different materials and this combination can go down to atomic level, meaning that in principle we can create two different alloys by composing them with the same percentage of atoms but placing the atoms in different ways (this is the case of the chalk you used to write on a blackboard and seashells: they are both composed of calcium carbonate but their consistency is quite different!). This can give you an idea of the basically unlimited number of possibilities. Also, with a bunch of elements in the periodic table, we have again basically unlimited combination of them. Proceeding by blind experiments like our ancestors did is time, and resource, consuming. Hence the new approach: let's build these alloys in the cyberspace (>>> virtual).

Machine learning algorithms are being applied to identify possible alloys that would deliver specific characteristics. An example is Intelligens, a US based company that has developed AI software that can help companies dramatically reduce time and investment in the search of new alloys (they claim a compression of 15 years into a month with savings up to 10 million $ in the quest of a specific alloy). An example of composition at atomic level is given in figure 35 and further details can be found here.

The ultimate goal is to use additive manufacturing to create the kind of material that is needed in terms of performance and characteristics at the same time as one is manufacturing the product (or a component). Ideally, rather than looking for a material that would be fitting the requirements and then finding ways of using it in an industrial manufacturing process, a designer will specify the required characteristics and an AI based software will create the material in the cyberspace and then through additive manufacturing the desired object will be created, directly driven from the cyberspace. This would support, as this Megatrend is predicting, an on-demand production.

I do not think that this will become commonplace by the end of this decade but several "pieces of the puzzle" will start to become available. Economy of scale is a big obstacle on the way. We might be seeing this approach for very specialised applications with stringent constraints where price is not the point.

b) *design through Digital Twins*

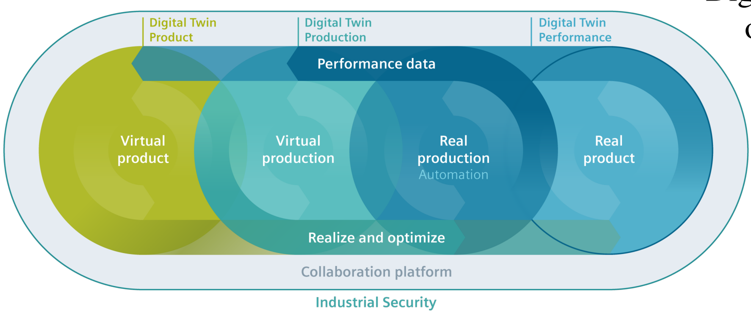


Fig. 37 Digital Twins are being used across the value chain. In the design phase a digital twin represents the virtual product and, in most instances, the design of the Digital Twin is the design of the product. Image credit: Siemens

Digital Twins have become an integral part of the manufacturing process, being used both as a tool and as a mirror of the product being manufactured. Actually, several companies are now starting to use digital twins in the design phase and in doing so they also create the digital twin of the virtual product.

The use of CAD - Computer Aided Design- has become much more sophisticated. Born as a drawing tools for engineers they have become platforms for product design. As such they embed all features/resources and constraints that characterise a given manufacturing process. In this sense the designer "cannot" design a product that would not be possible to manufacture by the present manufacturing processes/resources. In case the designer wants to enforce a characteristics that cannot be implemented in the current framework a red flag is raised and will need to be resolved before the design can reach the approval stage. Interestingly. some of these "platforms" allow simulation on the go, meaning that as a product characteristic/feature is being designed it can be emulated against a context (like existing components or part of the operation environment) simulating the interactions, the use of shared resources, the overall impact, thus providing immediate feedback on what it would look like. This emulation is created by the "under-construction" digital twin of the virtual product.

An interesting example is provided by the Municipality of Singapore: since 2019 they have created the Singapore Digital Twin. When a company wants to build something - like a new mall, deploy a service like self-driving taxis, it is required to present the project in terms of a digital twin. This digital twin will be embedded in the Singapore framework, interacting with the Singapore Digital Twin. Out of this interaction the Municipality is able to spot potential issues and request changes to the presented project.

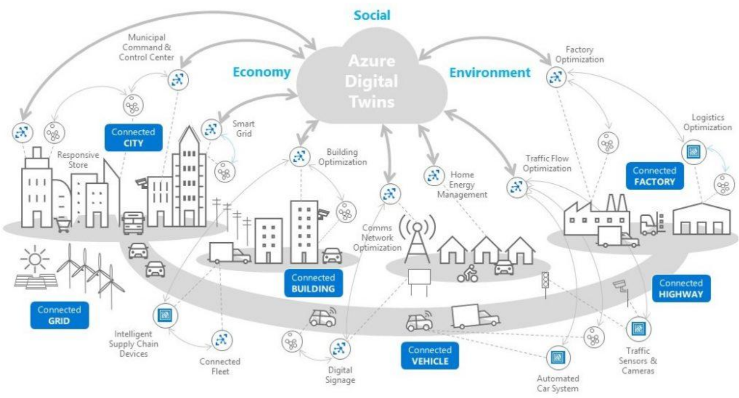


Fig. 38 IoTs in a city generates plenty of data streams that effectively provide a shadowing making it possible to keep the Digital Twin of the city in synch with the status of the city in quasi real time. The data are recorded, creating a Digital Thread and the whole is used through machine learning to [create an emerging intelligence](). Image credit: Microsoft

More than that. A city Digital Twin can be used to provide a living snapshot of the city. As such it can be used by citizens for better awareness on what is going on. That same Digital Twin can be used by a service developer to interact with the city in the cyberspace in the crafting of the service (in the previous paragraph it was the Municipality that used the service Digital Twin to assess its operation vs the city, here it is the reverse, the use of the DT to develop a service).

By the end of this decade we can expect a cyberspace populated by Digital Twins, mirroring both artefacts and people. They will provide a dynamic backdrop usable for the development of products and services. Furthermore, Personal Digital Twins may be used as interface component by several services (and for the soft part of products), in the same way that your smartphone is often used as an interface to products and services.

c) *On-demand production*

The efficiency of the distribution chains coupled with the flexibility of production lines have made possible an amazing change in the production processes and in the relation with the market (and with the end customer). Just two decades ago when buying a car you would have been offered what was available and what the dealer was expecting to be arriving. Optionals were limited and usually "pre-packaged" by the manufacturer. It was no longer "whatever colour as long as it it black" but it was a choice among a very limited pallet. Now you either go to a dealer and decide out of a long list of possibilities the car you want or you create your car “on-line” using the manufacturer customisation tool. The number of possible "versions" is now in the hundred of thousands. Just for fun I checked how many different versions are possible for the car I recently bought: 307,584!

It is not -yet- the market of one but it is getting pretty close. Notice that this variety is all provided in "hardware", products that are manufactured to specification arriving from the customer (in my case it was via the dealer but it is possible, as noted, to customise the car yourself using a software on your laptop or smartphone). Just imagine: creating your own car specs on your smartphone and "pushing" them to the robots on the assembly line for manufacturing! Now think about software customisation: that is something that in principle could be done as you are using the product, in the same way that you load new apps on your smartphone to do something specific.

The trend is quite clear, hence this Megatrend is not surprising at all.

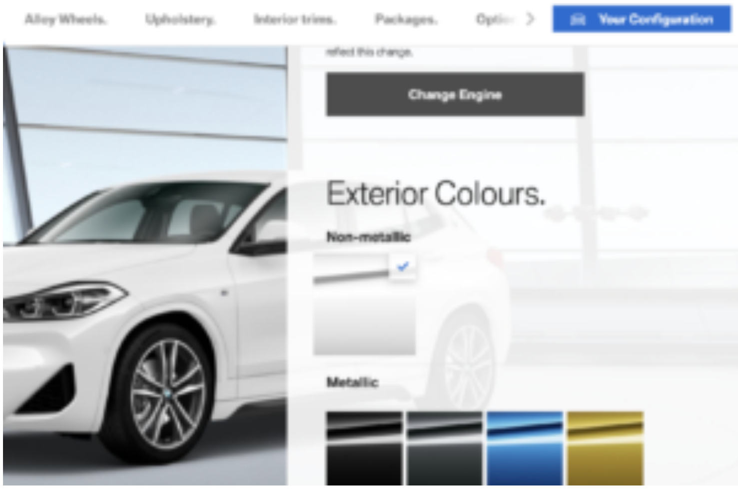


Fig. 39 Flexibility in present manufacturing systems makes possible to create "on-demand" your personalised product. In this image the BMW configurator lets you customise your car in ways that can make it "unique". Screenshot of the BMW configurator

In this decade 3D printing, additive manufacturing, will become more and more effective, i.e. more affordable and flexible. I do not envisage to have a 3D printer in my home, what I expect is to have the possibility of creating 3D models of objects, be it my foot or a gasket that wore out on the kitchen faucet. The new (top of the line) smartphones are starting to embed a Lidar sensor, something that can allow the creation of very accurate 3D models. Once created, an app will let me tweak it to fit my specific needs and then its production will be just a click away. The 3D printer that will "manufacture" perfectly fitting shoes or the new gasket can reside at a manufacturing plant (most likely in the case of shoes ...) or at the hardware store close to my house. One way or the other, I should be able to get what I want by the end of the day.

Big factories where the engines of the Industrial Revolution as well as its consequence (huge capital to pay for the manufacturing machines/assembly lines). Over time those machines have become more and more flexible and can, in principle, produce different artefacts. The reason why this has not happened is the parallel amazing evolution of the delivery chains. These have become so effective that it is irrelevant where production occurs from the point of view of the customer, so that production is actually happening where conditions are best, leveraging economy of scale. I just had a first hand example: ten days ago I ordered the printing of 3 photo albums, each one of its own size. I received the first one after 5 days and discovered from the tracking number that it was printed near London UK (it was an unusually large format). The second photo album was printed in Germany (and got to my home in Turin one week after ordering it). The third one arrived after ten days and guess what: it was printed in Italy. One would have expected that the one being printed closer would get sooner to me but that was not the case (by the way, I remember ordering a laptop and receiving it after 2 days: looking at the tracking number I discovered it was sent from Shenzhen, China).

This effectiveness of the delivery chain might improve even further in this decade as new tech for last mile delivery will become available (watch for the coming up Instant delivery).

On-demand production/manufacturing is a reality in the high cost item, like haute-couture fashion. The order triggers the manufacturing process and the factory will deliver the product directly to your home skipping all intermediaries (known as drop shipping). The textile industry is also moving towards on demand production: Kornit has announced in November the creation of a new biz line focussing on digital on-demand production management.

This will become more and more common pervading several sectors. One that is going to be significant for its broader implication is the Pharma. By the end of this decade personalised medicine will become mainstream and that will go hand in hand with the on-demand production of drugs, since each one will have to be custom made. The 2020 Researchers Night theme (November

2020) was on the evolution towards tailor-made drugs! For an overview of enabling technologies for personalised /precision medicine look here.

d) *Servitization*

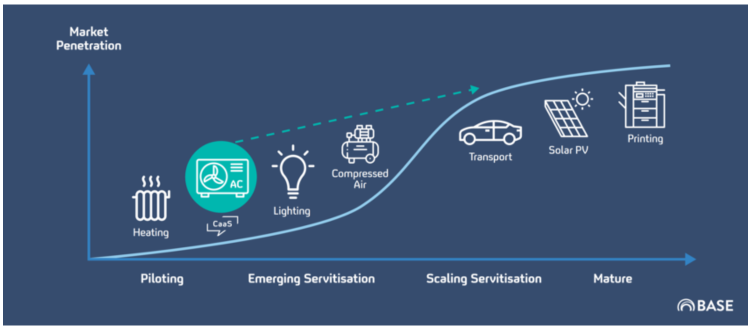


Fig. 40 The shift from product to services is increasing pace. In the figure, part of a World Economic Forum article, the level of maturity of servitization in the energy sector. Image credit: Basel Agency for Sustainable Energy

The transformation of products into services is not new. Several verticals have experimented new biz models aiming at generating continuous revenues by delivering services rather than selling a product. Digitalisation creates data, the orchestration of an ecosystem exploits them, often leading to the creation of more data. In addition, direct and indirect connectivity makes possible to keep the image of a product in the cyberspace, resulting in a direct link between the product's manufacturer and the customer. More than that. If the product was designed to support open connectivity, ecosystem players may access and get feedback from the use of the product delivering data (read functionality/services).

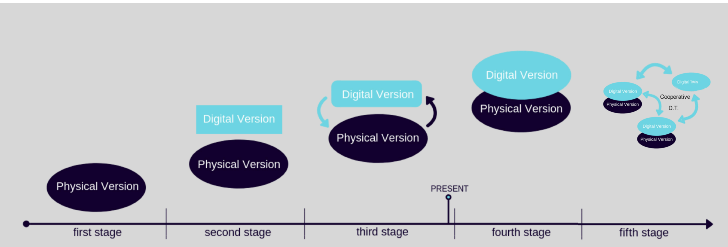


Fig. 41 The five stages of evolution of a Digital Twin. At present most of them are at stage III, with a few examples at stage IV

During this decade we can expect that several products will have a digital twin, their counterpart in the cyberspace. Differently from today, where the digital twin is a mirror of the product, in the coming years the digital twin will become an integral part of the product with some functionality being offered through the digital twin (DT at stage IV). This means that by adding functionality to the DT one is actually adding functionality to the product. It is, obviously, easier to add functionality in the cyberspace than in the physical product and this will stimulate the shift towards a service paradigm. On a longer time frame I would expect DT at stage V collaborating in a mesh network and each one relating the relevant results to its physical twin - see figure 41. This will also be a way to create a multitude of services in the cyberspace (with very low transaction cost) with instantiation to the physical twin based on relevance and needs.

Notice that servitisation is not restricted to the leverage of software over hardware. It is also about the managing of hardware "with software": think about the shift from "owning" a car to renting it as you need (may be with a driver, like a Uber like service or without, like Car-to-Go). Our cars are basically sitting idle most of the time, parked somewhere. By having an effective way of "summoning" a transport means, when needed and wherever we are we can get rid of the ownership of cars (MaaS - Mobility as a Service). This would reduce significantly the number of cars (some estimates that NewYorkers could get the same level of service with just 40% of the cars actually present in New York).

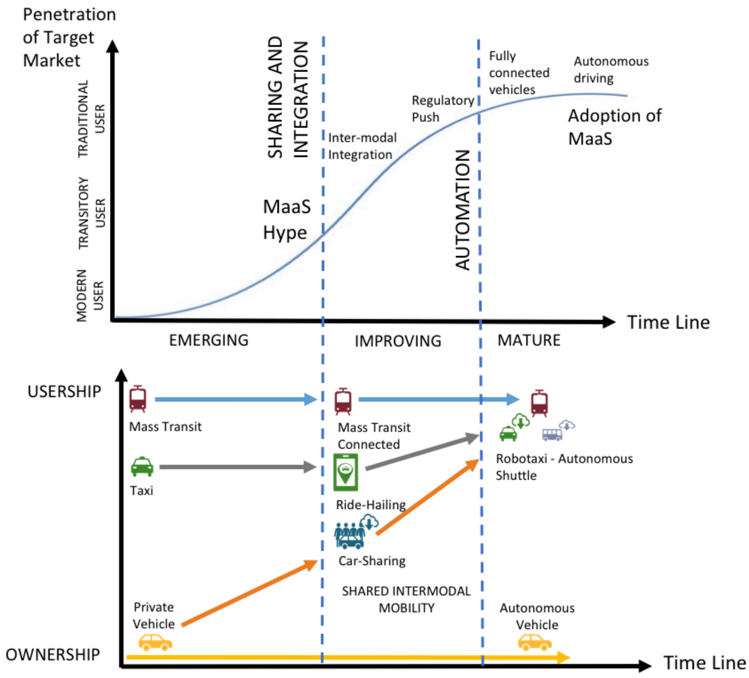


Fig. 42 Two interesting graphics indicating the evolution in the adoption of MaaS, from an emergent to a mature landscape (full maturing in the following decade) and the corresponding decreasing level of ownership. Notice the two big enablers, accelerators: first the software based sharing integration and second the automation of vehicles. Image credit: Bax&Company

In the MaaS area we are expecting an increase in sharing mobility, as shown in the graphic and an integration of sharing resources. This is made possible by supporting platforms and by a growing intelligence (machine learning and data analytics) that can pre-plan resources allocation at the macro scale plus interaction with personal agents (in the future personal digital twins) at the micro scale. By the middle of this decade we can expect an uptake in sharing integration (it was supposed to happen already in the first part of this decade but the ongoing pandemic and social distancing are slowing down the uptake as people are feeling more comfortable in using their private vehicles - for an interesting analyses on the shift on transportation's preferences look: here , here , here , here and here. Each of the linked reports addresses a different aspect but all agree the general public is less inclined to use public/shared transportation for fear of contagion. Clearly the attitude will change once the epidemic will be over but that will take a few years).

The second big shift towards MaaS, to happen in the following decade, is expected to be fuelled by the advent of fully autonomous vehicles. At that point any vehicle will be perceived like a public bus and you "use" a bus when needed, you don't buy one just in case you need it!

The Digital Transformation is at the core of both aspects of servitization: for the first one (delivering services by flanking a product) we are seeing the impact at the micro-level, the shifting perception of the end consumer on the value of a product, for the second one (sharing of resources through a software orchestration) we are seeing the impact at the macro-level, the shifting perception of needs.

The servitization is progressing in several areas, increasing in depth, value and breadth (I used MaaS as an example but we have similar examples in many verticals). It is also driven by the need to decrease the impact on the planet resources: using the cyberspace and moving atoms to bits decreases the footprint. This, at the same time increases the focus on services. For more on these specific aspects read the nice article from the World Economic Forum.

Selling a service is quite different from selling a product and it requires a different organisation. This is why it is not so easy for a company to make the shift.

When selling a product the "manufacturer" relies on a delivery chain and on resellers, it is basically decoupled from the end customer. Not so when selling a service. In this case there is a direct relationship with the end customer (and with the users). Also crucial is the fact than when you sell a product you are unlikely to see that customer for an extended period of time (depends on the product life cycle but it is usually measured in years): when you sell a washing machine that customer will not come back to buy a new washing machine until it has worn out (and if it wears out too rapidly the customer will look for a different brand!). However, your revenues have been made at the sale time. On the opposite, if you are in the service business you are going to interact with your customer frequently, actually, the more frequent the better, since you are generating revenues out of repeating use of the service.

The reason for the "decoupling" on the value chain (the separation of the manufacturer from the end users/customers) is the consequence of the high transaction cost occurring as you interface one player with another. The digital transformation, by shifting processes in the cyberspace and using data, slashes transaction cost thus making it possible to connect directly the players (most of the time this connection is mediated by machines/software). Industry 4.0, among other things, makes connection across the value chain “cheap" and "effective". This possibility can be leveraged and turned into a potential for revenue generation. In turns this stimulates the flanking of services to products.

Hence, to wrap up, there is a continuous growth of service offering, including services that are associated to products and, of course, service delivery can be instantaneous (on demand) and can be easily customised, thus fuelling this Megatrend.

e) *Instant delivery*

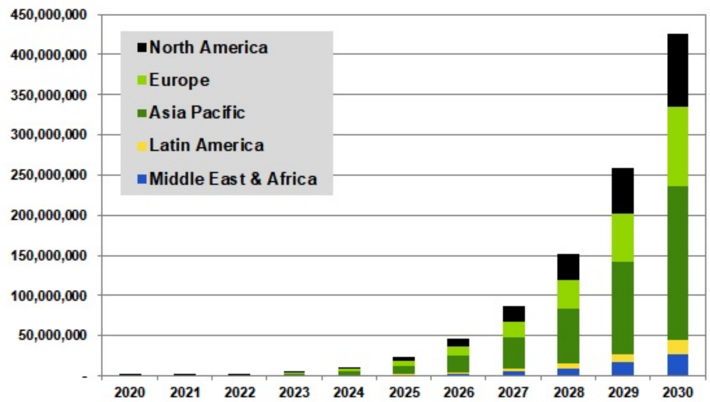


Fig. 43 Estimated growth of drone delivered packages, worldwide. Image credit: Guidehouse Insights

Logistic chains are one of the marvel of today's world. They work (most of the times) seamlessly and are so effective that you can get your delivery within a single working day (it does not work for any place and for any type of goods but I can vouch that I can get a number of Amazon delivery within 24 hours most of the time).

This Megatrend foresees an immediate delivery, lets say within a few hours and even within an hour, for most types of goods and for most location. I don't think this will be feasible in general but that "instant" delivery will become part of the daily life of many people in many situations by the end of this decades is a reasonable expectation.

First consider that 68% of the planet population will be living in an urban environment by 2030 and 730 million people will be living in one of the 31 megalopolis (more than 10 million inhabitants) by the same date. This high concentration of people in urban environment creates poles of attraction for market and allows the creation of effective hubs for the logistic chain in the last (few) miles.

Second consider that robotic delivery, including drone delivery, is progressing rapidly with the big guns (Amazon, Fedex, UPS, ...) all running trials.

It is not just the big guns experimenting with autonomous delivery. Big retailers chains are also interested and a few have started trials, as shown in figure 45, a [delivery using a Boston made Deuce Drone by Rouses Markets](#) in Alabama (a store chain with 64 stores employing 7,000 people).

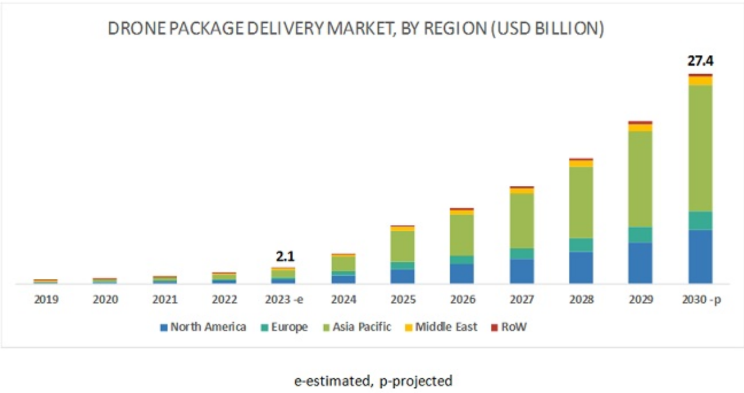


Fig. 44 Estimated market growth for drone delivery worldwide, expected to reach 27.4 B$ US by the end of this decade. Notice the lion's share taken by Asia/Pacific region followed by US as a distant second. Image credit: Markets and Markets

Emergency services are also using drones to deliver first aid kits, drugs and food to areas that are isolated. All of this is fostering technology evolution and we can expect to have more affordable and effective drones as time goes by.

As shown in figure 44, the [market for drone based delivery](#) is expected to grow significantly from today's basically not existing to 2.3 B$ in 2023 and up to 27.4 B$ in 2030. Most of the market is related to delivery of packages under 2kg of weight (above that bigger drones are needed to carry the increased load). Also, projections indicated that the segment of longer range delivery (over 25km) is expected to grow faster.

Fig. 45 Drones delivery has entered into a trial phase in several market segments. In the photo a drone delivery by Deuce Drone on behalf of Rouses Markets. Image credit: PYMNTS

Autonomous delivery robots are widely used in warehouses, in hospitals and are now starting to be used on factory floor. Trials are running for using autonomous "carts" as freight delivery in urban environment and the pandemic [has increased the interest](#) towards contact-less delivery such as the one provided by autonomous freight vehicles designed for the last mile. Supermarkets and big stores are the prime focus for their deployment.

I am not sure that both drone delivery and autonomous freight delivery will become the norm by the end of the decade everywhere. Most likely there will be some areas that will make use of this delivery type (mostly because of geographical location and a lay of the land that is conducive to this type of autonomous delivery) whilst others will see autonomous delivery more as an exception.

f) build/customise as you use

The flexibility of manufacturing and the softwarization of functionalities result in a broad range of adaptations for most products. If you want to think at something you already own, think about your laptop. You had the choice on the chip type (how many cores, the clock frequency), the graphic board, the storage capacity, the screen size. It might not seem a lot, but when I bought my first PC I

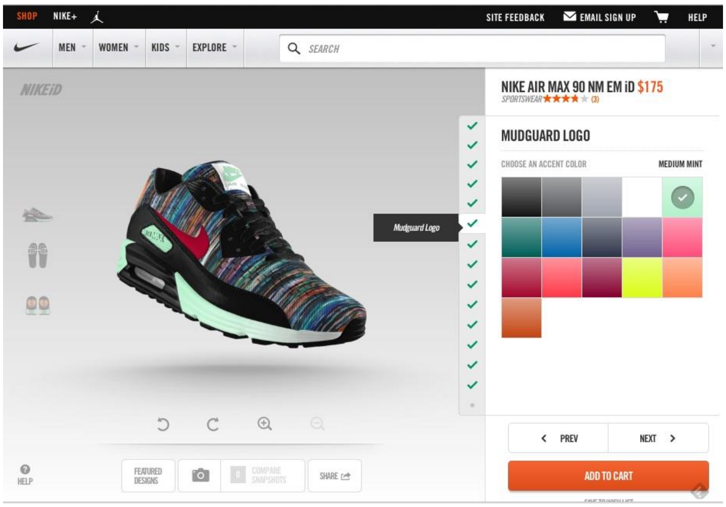


Fig. 46 Customisation is becoming possible more and more. Manufacturers and retailers are using it as a competitive advantage. Visibility on user's data push customisation into personalisation through the life cycle of the product. Image credit: Nike

had no choice at all! Then think about the software: here the choices are so broad that it is most unlikely you will find a laptop that is exactly like yours (I am talking about applications, not about the data). In the case of your smartphone, the hardware choices are much more limited on the hardware side but are [practically limitless](#) on the software side, with a pool of 2+ million apps to choose from.

This trend towards customisation of products as you buy them will continue, as already noted in the section "on demand production". Furthermore, for several products there will be the possibility of keep customising them as you use them. Customisation through usage is obviously happening today for your smartphone (and several other devices embedding a computer, like the television set). You tweak your devices to better suit your needs and way of using them (as an example go to YouTube and look for "customise iPhone 12", you'll see plenty of videos to guide you through the unlimited possibilities of customisation -worth exploring a bit, I discovered many "things" I can do with an iPhone I was not aware of ...).

Even more interesting, in the future, but it is already happening today in a limited way, your device will learn the way you are using it and will self-customise to better fit your habits (as an example your new iPhone learns your way of charging it and will self regulate the charging to decrease the wearing out of the battery ...). As artificial intelligence gets embedded in a device, it will make the device aware of the way it is being used and will therefore finely tune the interaction to better fit that type of use. This kind of customisation, based on the understanding of a person usage and context is often called "personalisation" to distinguish it from the one, customisation, that does not require a knowledge of the user. Interestingly, the possibility to connect a product through its usage phase to the manufacturer (or to a service provider) enables the personalisation of the product, increasing the perceived value. The more you use it and share date with the producer/service provider the better the product will meet your needs.

The shift towards voice interaction, and within voice interaction towards natural language interaction, provides a further boost to device intelligence and to its adaptation. By the end of this decade you can expect to be able to talk to most of your devices, directly or via an orchestrator, like Alexa, the same way you would be talking to a friend or a colleague, that is, expecting that the device keeps memory of previous interactions and you can start the next one from where you left out with the last one. Also, we can expect that the use of voice interaction will allow the device to capture our moods -annoyed, bored, happy, stressed,...- and tune the interaction accordingly (sentiment analyses).

The presence of a device, in terms of functionality, both in the physical space as well as in the cyberspace will greatly increase flexibility and customisation potential. Additionally, the existence of a personal digital twin that can interact with the digital twin of the device will make possible to have a backstage customisation even before we start using the device.

What is true for products will be true for services and this might happen sooner. It is already happening: our profile, created by the entertainment service providers becomes a sort of personal digital twin (in the entertainment sector) and this is used any time we access entertainment services with our identity, so that, as an example, I will find customised (personalised) recommendations on what to watch both when I am sitting on the couch at home and when I am in a hotel room thousands miles away (the offer may differ based on location for copyrights reasons, but the service will still customise the offer to my tastes).

g) recycling/circular economy

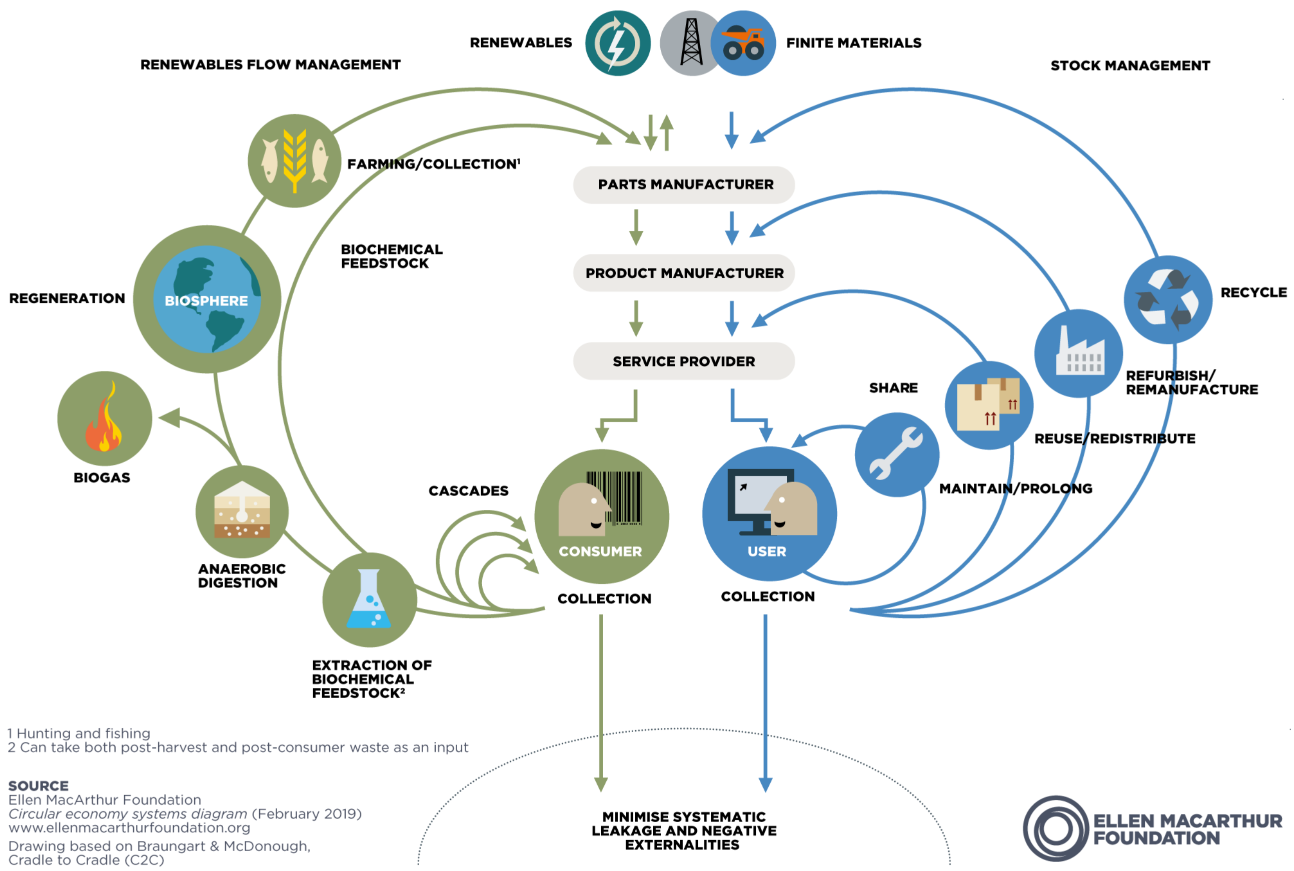


Fig. 47 A circular economy representation having in the central part the value adding chain (component production, final product manufacturing/assembling and service creation, on the right end side the usage part including all life extending activity and eventually the parts recycling. On the left hand side the use of waste and its reprocessing by nature to feedback the production chain. Image credit: Ellen Macarthur Foundation

We have been talking about recycling for a few decades, and we have been taking action to implement recycling at least in part (differentiated waste collection and processing is surely part of it) and more recently we have been discussing the possibility of a circular economy where cost of managing the end of life-cycle of products can actually be turned into value generation. This Megatrend on instant things availability is deeply intertwined with both recycling and circular economy and it foresees a much broader uptake of these paradigms throughout this decade.

From a physical-mathematical point of view a circular economy would be impossible, since it would go against the second law of thermodynamics, however from an engineering point of view (approximation) it can be done. Besides, there is a trick: we look at circular economy on our planet but this is not a closed system, we get "input" from the Sun, energy, and we can use that energy satisfying the second law.

Anyhow, when we talk about recycling and circular economy we take an engineering standpoint and an economist standpoint, that is let's do what is possible and make the most of it!

As shown in figure 47, production of value - products and services - (interesting the representation of the steps where you see services following the product: this is in line with the trend of flanking a product with services and enriching the product functionality and user experience through services) leads to use (user) and consumption (consumer).

Usage is addressed by a number of actions that maximise the use of that value and more specifically:

- sharing economy: using the product by several parties, maximising its benefit AND reducing the need for duplication. An obvious example is car sharing. Rather than having several cars, one per user, we can share the use of a single car across several users under the (true) assumption that a user is using a car for only a fraction of the time (on average our cars are sitting idle for over 90% of the time, parked somewhere). By using software and platforms we can make a car available to several users. Several studies have been made modelling different usage scenarios (a very nice one can be found here) and they all show that there is not a single solution fitting all use cases, but all car sharing approaches lead to a significant decrease in the number of cars required. This is good if you look at it from the point of view of raw material usage -producing fewer cars requires less raw materials- it is good in terms of economic efficiency from the point of the user spending less to move from A to B, it is good in terms of urban space occupied by cars, fewer cars being parked around, BUT it is bad for car manufacturers that would see their market volume squeezed to the point that present manufacturing processes and competition environment would collapse as they have been finely tuned for a market buying some 70+ million vehicles per year, difficult to sustain when market will shrink to less than 40 million per year), it is bad for the many companies looking after the maintenance of the cars, it is bad for those selling gasoline, it is bad for car-washers…;
- proactive maintenance and continuous improvement/extension of functionalities: think about the new features you get as a new OS becomes available: you still have the same computer but it gets better with the new OS. This extends the life of products and again it is good for the environment and for the user but it decreases the substitution market, leading to decreased sales. In software this has become a major issue that has led several software company to shift to a subscription model, since the sale of a perpetual license would result in a shrinking market;
- reuse and redistribution: we have seen this happening in areas like wedding dresses, with companies that are offering customised rentals (they take care of modifying a wedding gown to fit the bride). A bride to be can rent a perfectly fitting dress out of a very large selection for as little as 150$ (compare this to the 2,000+ $ needed to buy one). That dress will be used only once by the bride and upon return to the renting company it will be cleaned and restored to pristine condition waiting for another bride to be. Notice that this is different from car-sharing. Here after each use the dress is reconditioned and before being used again it will likely be modified to fit the new bride. However, the bride that uses such wedding gown is a bride that does not "buy" a wedding gown, thus shrinking the potential market;
- refurbishing/remanufacturing: the refurbishing of products is nothing new, the big department stores have been doing that for decades. It just happens that it will be further extended. Several companies are now advertising a service-like contract, you buy a smartphone and every year you can return it and get the new model for a minimal yearly fee.

The old (one year old actually, so still young) smartphone will be refurbished and placed on the market once more (at a lower price). I have got several refurbished items, like Nikon lenses, tablets... and they all work flawlessly at a fraction of the original cost. Here again we are basically extending the life cycle of a product, hence decreasing the total market;

- component and raw materials reuse: for certain products it is possible to disassemble them once they are returned and in some cases to extract the basic raw materials (like copper, gold...) for their reuse in the manufacturing of other products. In this case we are not seeing a decrease in the potential users' market but of course we are decreasing the market of some parts (like raw materials) of the supply chain.

By the end of the decade this Megatrend predicts a significant increase in all of the above aspects of recycling and, as pointed out, this is good in many aspect BUT it is bad in terms of market space (fewer products will be sold). However, it is also true that all processes involved result in value creation and thus in revenues opportunities, although these opportunities are not -usually- harvested by the original producers.

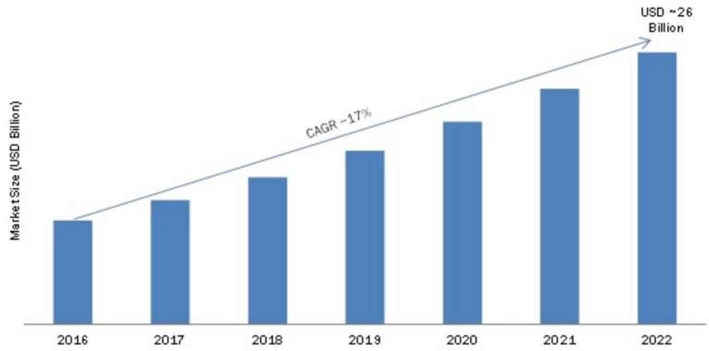


Fig. 48 Global Market value growth of recycling in electronic waste. As shown in the graphic, it is expected to grow at at 17% CAGR, reaching 26 billion $ in 2022. The growth is the result of evolving recycling technologies that decrease recycling cost and foster reuse of materials, thus creating revenues. A further important factor is the growing awareness of the impact of electronic waste on the planet and a more environment conscious culture all over the world. Image credit: MENAFN

On the consumer side (left part of the graphic in figure 47) we see products that are transformed by use into "waste". In this case the challenge is how to make use of the waste to feed different value chains like using waste as fuel (or to create fuel). We already have a variety of thermo-valorisation plants and you can expect to see many more of them and with a higher efficiency in this decade. The trick is to exploit waste in such a way to generate value (like heating of city's buildings or electricity) and for the residual material to be regenerated by natural processes (using Sun light) to return to a state of natural materials that are present in the environment. All of this is feasible, from a technical point of view, the real challenge is to make it affordable from an economic point of view (that is, it should be cheaper to dispose waste through thermo-valorisation than dumping it into a landfill).

This Megatrend promises that by the end of this decade we will be able to do this, and that would be an amazing result!

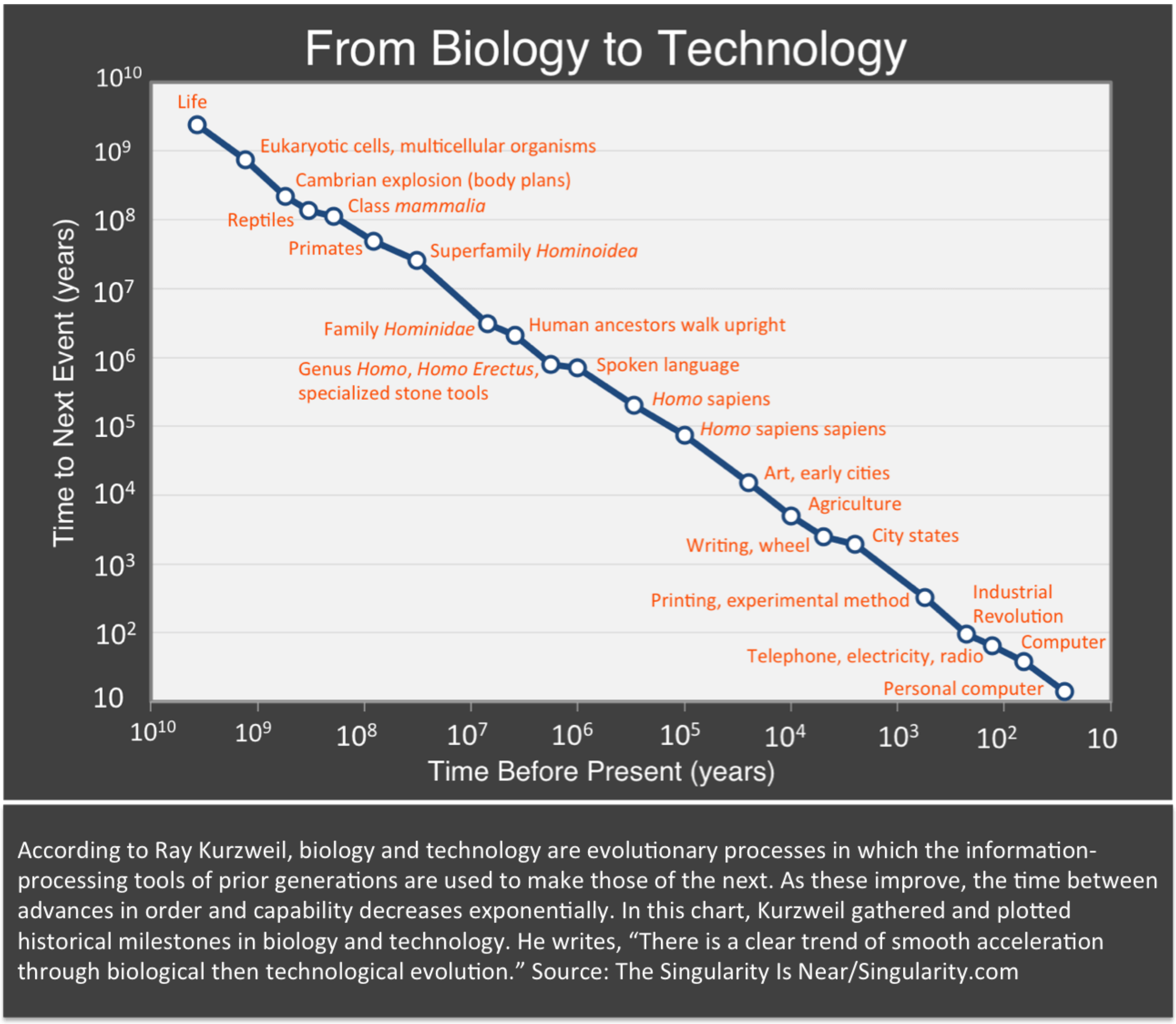


Fig. 49 A very intriguing graphics where biology and technology are seen as forces of evolution, with technology pushing the envelope in the last fragment of Earth history. The graph was conceived by Ray Kurzweil as a way of showing that each "generation" builds up on the results achieved by the previous one, both in biology and technology leading to an acceleration. Image credit: The Singularity is near. Singularity University

This Megatrend is about the never ending explosion of knowledge. This looks like a very recent phenomena, however, if we go back in time and take a broad view we can realise that the growth of knowledge has characterised not just our history on the planet but the whole "history/evolution of life on the planet" as it has been very well observed by Ray Kurzweil in his book "the Singularity is near". I would go even further by saying that knowledge of some sort was predating life. Of course, you would need to stretch a bit the meaning of knowledge but weren't the primeval molecules learning how to assemble in different ways, exploring the huge possibilities of chemical reactions and finding the ones that would lead to an advantage over others? You may object to this stretching of the concept of knowledge but I feel that the path of evolution that has just started, with artificial intelligence, self-learning machines and cognitive digital twins requires a re-thinking of the concept of knowledge.

Let's go back for a moment to Ray's graphic shown in figure 49.

In the graphic you see a plot of milestones that characterised quantum leaps from one stage of knowledge to the next one, spaced in time. Notice that the measuring stick is in order of magnitude, i.e. it is exponential. Thus what seems to be the same spacing is actually representing a compression of one order of magnitude (ten times faster). Also, you see that the knowledge steps included for most of the graphic (between 4 billion year ago to some hundreds of thousands years ago) are resulting from an evolution that has been driven solely by biology, that is chemistry and natural selection. Since a few thousands years ago technology (agriculture, the invention of the wheel and lever, the invention of writing) has started to flank the biological evolution. Notice also that biological evolution requires plenty of time and although some biological evolution happened in the last hundred thousands of years it is technology evolution that has made a difference (most scientists would agree that if you could pick up one of our ancestors from 10,000 years ago as a baby and you would nurture him as a contemporary baby he will be be indistinguishable from our contemporary fellows). However, if you pick a grown up aborigine that has not come into contact with modern civilisation the difference with one of us would be huge also in terms of capability to understand the world. Technology makes a deep imprint on our mindset and on our capabilities to acquire knowledge.

What is most interesting in this graph is the underlying theses:

technology is extending, and accelerating, the evolutionary path set in motion by biology

The acceleration, exponential growth of technology, is perceived as linear when you use a logarithmic scale (as it is the case in the graphic) and since we are sensing our world through senses that are basically logarithmic in terms of sensitivity (a sound has to be 10 times stronger to be perceived twice as strong, light intensity needs to be 10 times greater in order to be perceived as twice brighter...) we are not experiencing an exponential increase but a linear one: yesterday was not that much different from today and tomorrow will look pretty much the same as today. It is only by taking a step back that we can start perceiving the exponential growth.

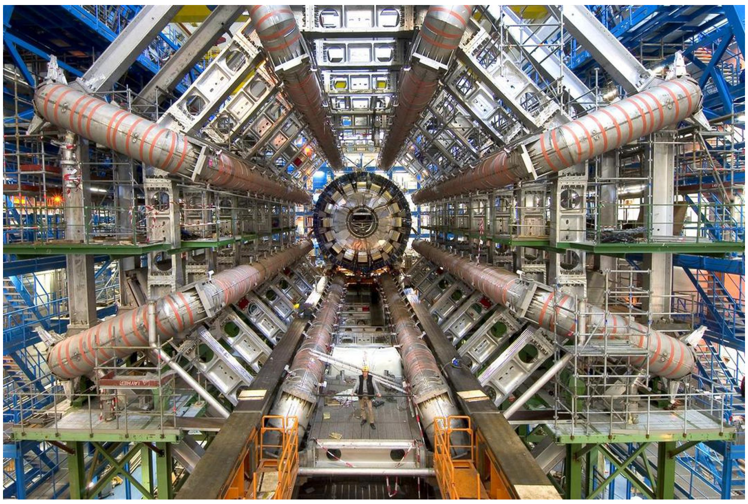


Fig. 50 The Large Hadron Collider, LHC, in Geneva lets scientists study the effect of particles collision at high energy. In the process it generates a huge amount of data, some 90 PB per year, a volume that is beyond human brain capability to process. Image credit: CERN

What is important is the association of "sense" (what we can sense) and knowledge, and this is exactly what this megatrend does. As we can sense more, our knowledge horizon expands. The inventions of the telescope and microscope have expanded our senses capability and our knowledge as a consequence. Today's IoT -Internet of Things- along with pervasive communications network and huge processing capabilities multiply the capability of our senses. Interestingly, I am naming "processing" as a fundamental component of both senses (to capture data) and knowledge (to make sense out of data). Think about the Large Hadron Collider at CERN: it generates some 90 PB of data per year plus 25 PB generated by correlated experiments (a PB is a million GB).

CERN opened up 300 TB of LHC experiments' data in 2016 and as of the end of 2019 the EOS storage system of CERN makes available over 3 billion files of data through open interfaces. The processing cloud of CERN processes every day 1 PB of data. It is clear that without this kind of computer power we could never extract knowledge out of the LHC. Opening the data without computer processing power will not increase our knowledge by an iota.

Now, this is pretty interesting because what we are basically acknowledging is that our technology, sensors in particular, is providing us with plenty of data, hence with a greater awareness of the world around us and consequently greater knowledge. However, without relying on technology to process those data we would not increase our perception of the world, nor our knowledge. The consequence is that in the evolution of knowledge we are forced to rely more and more on technology (and this goes well with what the graphics is showing, an evolution steered by technology).

However, we have reached an inflection point: we are now transferring the creation of knowledge to machines. Artificial intelligence is no longer mimicking (trying to mimic) our intelligence it is achieving a status of its own, it is becoming a complementary intelligence. Some people get scary by the idea of an artificial intelligence that we do not understand but I can see many parallel with "things" that we are perfectly at ease with. Think about having a nice meal: have you ever stopped enjoying the meal by the reflection that you are eating it with a fork and knife, both of them tools that you would not be able to manufacture by your own and that at the micro scale you don't even understand how they can possibly work? If you beg differently, send me an explanation of why the atoms that make up a fork result in a solid tools that does not bend whist the atoms that are in the spaghetti you are eating result in something that bends and wrap around the fork! The point I am making is that we take for granted a huge amount of things and we build what we call knowledge upon very shaky understanding of the deep reasons: you can pull a box with rope, but you cannot push that box using a rope.... What we call "common sense" makes up a big chunk of our knowledge.

I bet that in the future we will become more and more familiar with artificial intelligence (we already are when it is hidden, like when you talk to Alexa or your television, yet that works because of AI) to the point that this will become part of our knowledge. I know how to calculate a cube root: I just pick up my smartphone and press a few keystrokes: voila!

If you think this is reasonable, let me move one step further introducing Cognitive Digital Twins - CDT. A CDT is mirroring a certain set of knowledge, be it the one of an enterprise or of a person. Suppose you have your own Personal CDT. That CDT will mirror your knowledge and it can come handy in several situations, even to impersonate you at some meeting... or, even better, in delivering knowledge services on your behalf and generating revenue (for you). Think about your expertise in using a photo editor: you could lend (at a price) this expertise to an agent that will be using your CDT to offer consultancy on demand to people needing your type of expertise.

Now, if you have a CDT you might also be interested in using it to remember things that are somewhere in your brain but that just seems to be out of reach, they are on he tip of your tongue and the CDT may turn them into vivid thoughts. What about using your CTD to increase your knowledge. It may roam the web, connect with other people CDTs and taking into account what it would be useful for you to know at a certain point in time and space teach you what you need to know.

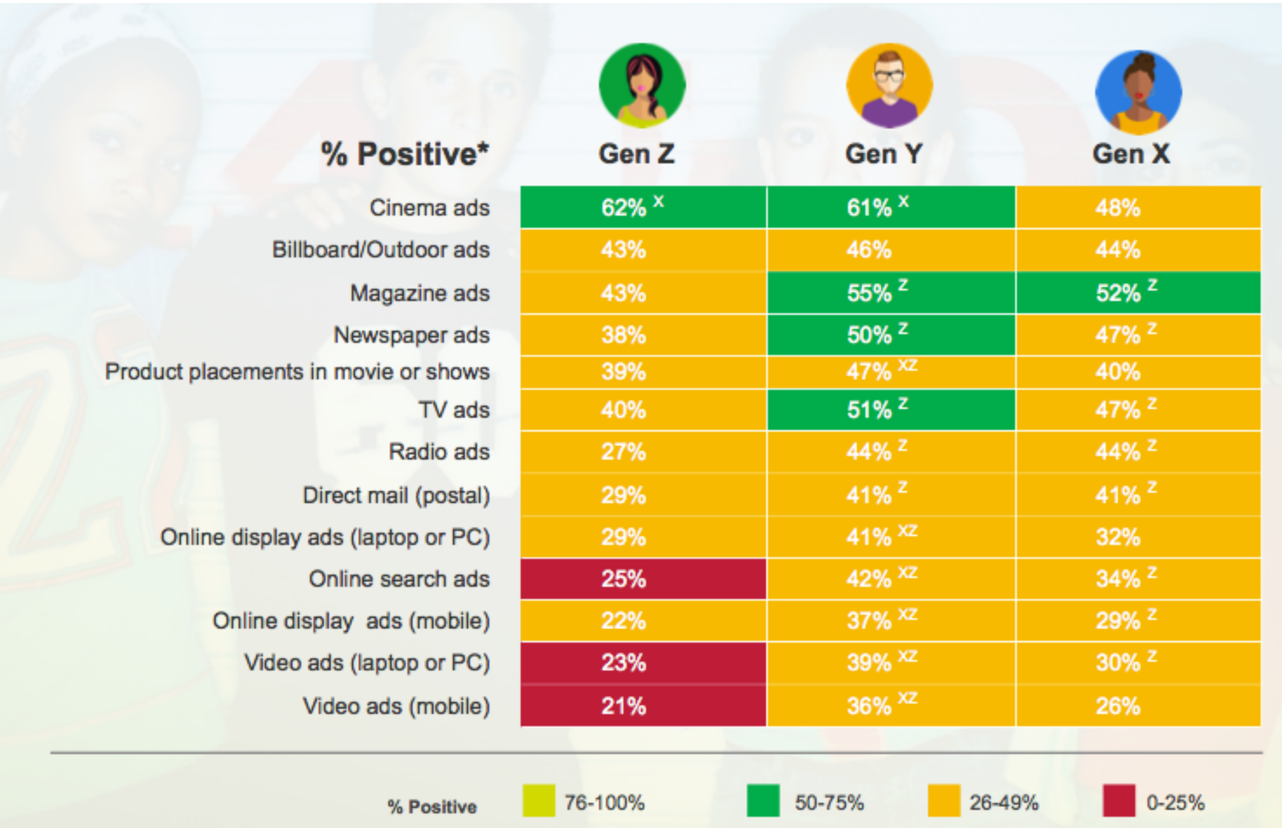
Wait a moment. Why couldn't I use my CDT as an extra knowledge "bank" so that I actually don't need to acquire a certain knowledge as long as I can seamlessly access to that knowledge through my CDT (whether it is already embedded in my CDT or it can be summoned at need by the CDT is irrelevant for this discussion). Am I not using today my smartphone when I need to calculate a cubic root of a number without any idea how that should be done? To me the result is what matter and of course the knowledge I need to get the result, not the one to produce the result all by myself. A CDT at stage IV (autonomous CDT) and even better at stage V (cooperating CDT) would be able to flank my knowledge with all knowledge that I might need here and now.

Here comes the real, impressive power, of this Megatrend: Sense and know anything, anytime, anywhere. A CDT seamlessly in synch with my brain would be able to deliver on this promise.

Personally I do not think that we will get there by the end of this decade but I have no doubt that we can make significant steps in that direction.

Can we still call that knowledge? I would say so. At the same time this direction is a direction towards a further evolution of our species, towards a symbioses with machines. The problem is not just what will be the upsides and downsides of this evolution at personal and societal level. It is also about a potential digital gap between those having a CDT and those not having it that makes the one we are talking about today a child's play.

14. Disruption of Advertising



% Positive*	Gen Z	Gen Y	Gen X
Cinema ads	62% X	61% X	48%
Billboard/Outdoor ads	43%	46%	44%
Magazine ads	43%	55% Z	52% Z
Newspaper ads	38%	50% Z	47% Z
Product placements in movie or shows	39%	47% XZ	40%
TV ads	40%	51% Z	47% Z
Radio ads	27%	44% Z	44% Z
Direct mail (postal)	29%	41% Z	41% Z
Online display ads (laptop or PC)	29%	41% XZ	32%
Online search ads	25%	42% XZ	34% Z
Online display ads (mobile)	22%	37% XZ	29% Z
Video ads (laptop or PC)	23%	39% XZ	30% Z
Video ads (mobile)	21%	36% XZ	26%

Fig. 51 Advertisement targets specific market audiences and these audiences and the way to reach them changes as technology and social framework advance. In this chart the result of a polling on Gen Z (born between 1997-2012), Y and X (parents of Gen Z kids, born 1965-1980), sensitivity to various form of advertisement. Notice the differences of Gen Z with previous generations. Image credit: Kantar Millward Brown

As offer variety exploded customers got the upper hand, they had a choice. Hence, products and service offer had to compete to get customer interest. Whilst it is true that advertisement can be traced back in millennia, the modern advertisement goes back less than 200 years when two factors came into play: growth in variety and presence of a media to support advertisement (printed newspapers). One, the variety, stimulates the need to advertise, the latter provide the means.

Both of them have kept "growing".

The variety of products that we can "reach" today would have been unimaginable fifty years ago: Amazon sells some 12 million products and on its virtual shelves displays some 350 million products (sold by third parties). These numbers are just mind boggling.

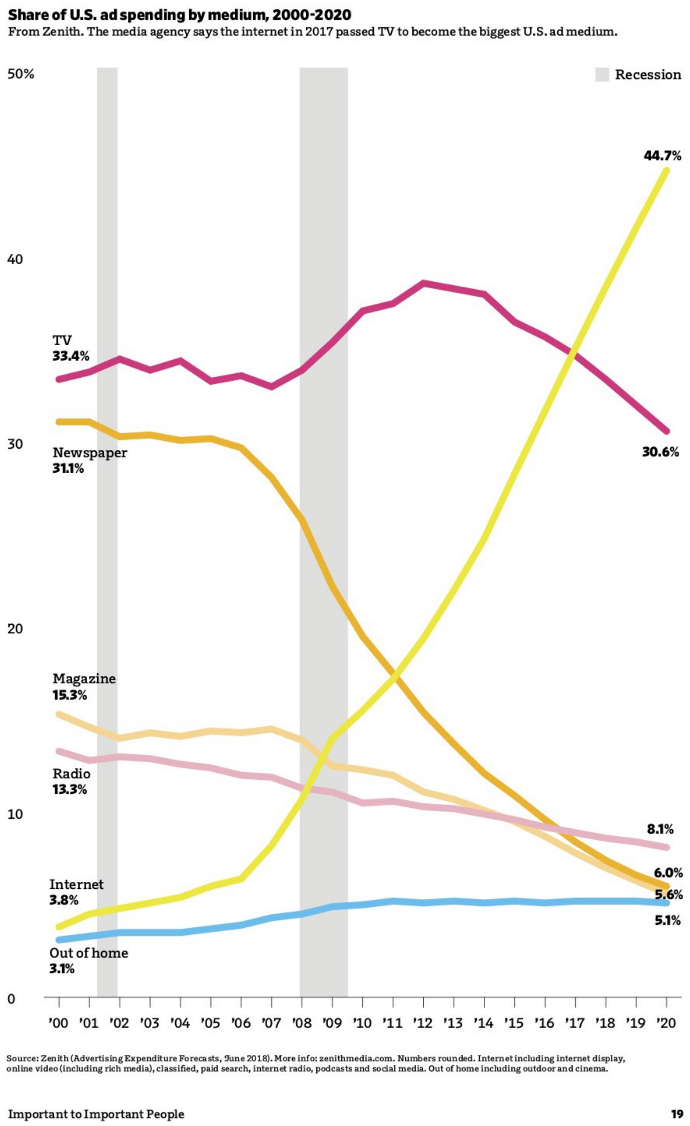


Fig. 52 Spending on different media for advertisement in the US. The yellow line, you guessed it, is the spending on digital advertisement. It exceeded spending for ads on radio in 2008, magazine in 2009, newspapers in 2012, television in 2017 and this year it represents 50% of overall spending in advertisement (in the US). Image credit: Zenith, Advertising Expenditure Forecast, June 2018

The numbers, variety of means to reach customers and deliver advertisement has also grown immensely, in number and in reach. Ads are still on newspapers, but we get them through radio, television, movies (and *in* movies as products being used by actors and actresses and therefore look so much more appealing), public screen displays, shop windows and banners around the city, leaflets ... However, today most exposure to advertisement is via the web or in general what is called Digital Media (as opposed to Traditional Media). A whole new "marketing science" has flourished and plenty of companies are working to make digital marketing effective (in reach, cost, measurement) with Google heading the pack by far.

However, it is not a one way street: you have a product and you have a variety of means to advertise that product but it is more and more about the kind of people you need to reach and the news is that these people are rapidly changing their habits and their perception of advertisement channels and messages. As an example, shown in figure 51, representing the result of a study on how different generations (Gen. X, Gen. Y and Gen. Z), the new customers approaching the market, Gen. Z, have a quite different perception of values and are used to different communication channels and ways of using them.

This is actually what this Megatrend is

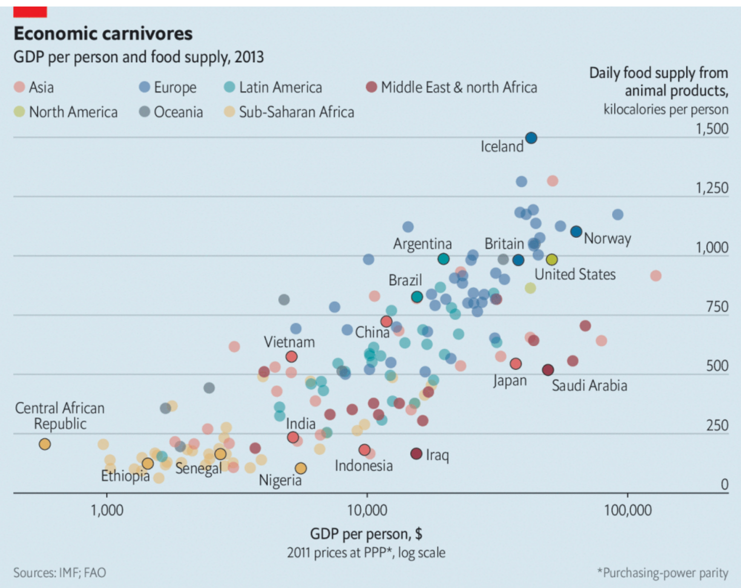
all about: changes that will lead to a disruption by the end of this decade,

The point is that in this decade a new player will enter the game: artificial intelligence. AI has been used for several years to profile viewers, leveraging on the fact that digital interaction is easy to track and provides plenty of data (where you are, how much time you spend on a page, how many times you come back to that page, what you have also been looking at, how you commented on a product on social media, how involved you are in social media, and so much more). Actually, today's AI is providing more insight on your tastes and whims that you are actually aware of. Based on this emerging intelligence about you the sellers can customise the ads to make them more effective and even change the price to meet your spending willingness (which, by the way, does not mean decreasing the price: when an airline spot your interest for a destination the ticket price is likely to increase! A good rule of thumb is to use a computer for search and a different one -not having your identity- to make the actual purchase).

However, and this is the point, AI has been used so far on the advertiser's side, to provide insight about you (me) and to increase the effectiveness of the advertisement. By the end of this decade it is expected that each of us will be using AI to improve our chance of selecting the right product/service and this is where the "disruption of advertisement" occurs.

Personal AI, embedded in our personal digital twin or in our devices will know even more than the advertisers since it will be able to track much more of us and it will continuously refine this knowledge and even intercept our moods finely tuning the advices. The advertiser's "power" will be greatly reduced and they will have to find new strategies to "push" the offer to the market.

15. Cellular Agriculture



The Economist

Fig. 53 An interesting graphic showing the relation between the GDP per person and the use of meet as food supply. It is pretty obvious the correlation between higher pro-capita GDP with higher meat consumption. Image credit: IMF, FAO

Meat provides much more calories than a vegetarian diet and this is somehow "coded" in our brain that steer us towards a meat based diet. However, meat is more expensive on the environment (since it is at the end of the food chain and -again the second law of thermodynamics- any step in the chain adds a cost) which in turns makes meat more pricey on the market, and hence affordable only to those that have a higher income. This can be seen in the interesting graph, figure 53, produced by the IMF and FAO where it is clear the shift towards a meat based diet as pro-capita GDP grows. In China the increase of pro-capita meat consumption has led from the 4kg of meat per person per year in 1961 to the 62kg eaten in 2013, a 1,450% increase in 50 years.

To "produce" a 170 g steak (6 ounces, a usual serving) you need 2,500 litres of water (674 gallons - it may actually requires ten times as much if you factor in the water needed in all processing and in all parts of the food chain). A serving of salad (including tomato and cucumber), on the other hand, requires only 80 litres of water (21 gallons). Interestingly a tiny cup of coffee has required some 130 litres of water (34 gallons) to grow the beans and process them...

Clearly there is more than water that needs to be taken into account when evaluating the environmental cost of food, but for sure it provides a first, although rough, metrics. On the other side you need to gauge the yield and you can use, again as a first rough approximation, calories. That 170g steak delivers 459 calories, that salad delivers some 160 calories, 1/3 of the steak, yet its "environmental" cost is 1/30! (let me reiterate that these are back of the napkin calculation, I did them just to give the feeling of what I am talking about. The actual numbers, once you take into account all aspects, fertilisers, antibiotics, land usage, machinery... may differ but, I feel that they will further increase the unbalance rather than decrease it).

Fig. 54 Artificial beef lab grown meat in retail supermarket emerging field of food production with label. Future trend of biotechnology, artificial food 4.0 concept. Image credit: iStock, Getty Images

Hence on one side we have the basic craving for meat (and fish...) that, as wealth increases globally, becomes more and more pressing, and on the other we have the low environmental efficiency of a meat based diet. The quest is on for a way to dramatically slash the (environmental and economic) cost of meat production to meet that challenge.

This Megatrend is predicting a solution by the end of this decade, through cellular agriculture.

Cellular agriculture is an emerging field aiming at producing meat without the animal! Through in vitro growth of cells the goal is to be able to create a steak equivalent at much lower cost, both in terms of environmental impact and in terms of product cost.

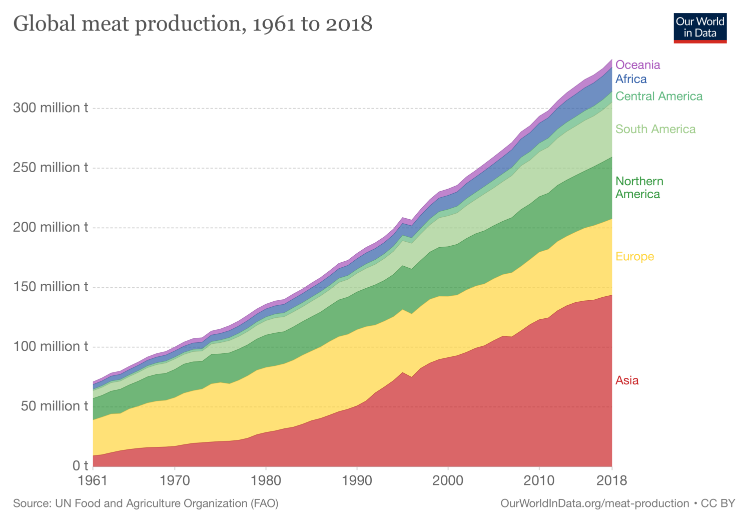


Fig. 55 The increasing growth of meat production is not going to satisfy the growing demand as more people are turning to a meat diet (because they can afford it economically). Image credit: data from FAO, graphic by OurWorld in Data

The first hamburger made with artificial/cultured meat, goes back to 2013, made by Mark Post, professor at the University of Maastricht, -you may want to watch this clip- but the real push towards large scale production was given by the US Federal Food Administration in 2018 that defined the regulatory framework.

There are already a few companies working to make this possible and, as shown in figure 54, products are already available on a few supermarkets shelves. So far, the production has resulted in ground meat and hamburgers, not steaks.

One of the problem is scale production

and its cost (in 2018 the cost for a "steak equivalent" was 50$). The expectation is that by the second part of this decade cellular agriculture will be able to deliver at a cost that is in line with the one of current "natural meat" but it will probably take quite sometime for industrial production to scale up anywhere near the current output of natural farming, More optimistic visions exist foreseeing an equal cost as soon as 2022.

Even in the eyes of the most optimistic observers this Megatrend is not going to have a big impact in this decade. The production volume that we can expect by the end of the decade will represent a very very tiny fraction of the overall meat consumption. Current world meat production (2019) is 340 million tons per year, the manufacturing plants that Aleph, an Israeli start up, is planning to build starting 2021 are targeting a production in the order of hundred to a thousand tons of cultured meat. It would take a million of them to match the current world meat production.

Nevertheless it is a sure bet that both cellular agriculture and alternative (veggie based meat) will play a growing role in the next decade.

*16. **Brain Computer Interfaces***

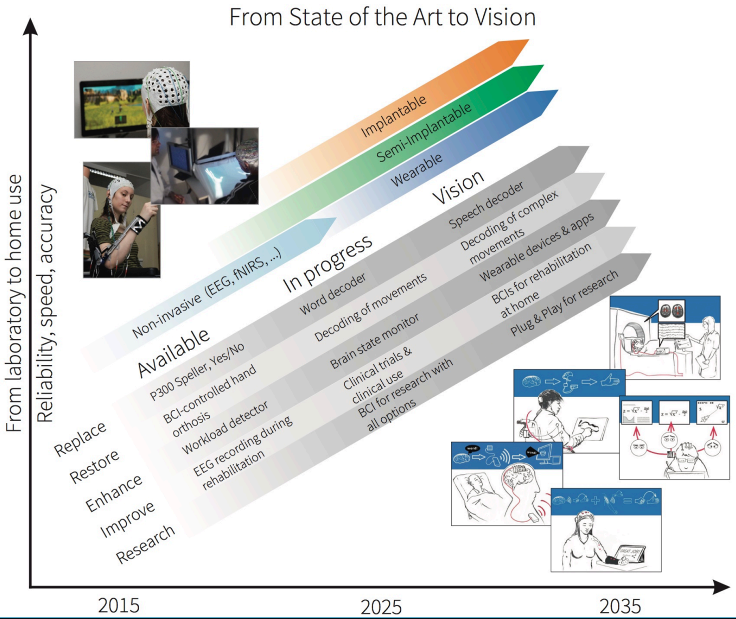


Fig. 56 An interesting roadmap for the coming two decades on the evolution of brain computer interfaces. Notice the categorisation of interfaces in wearable, semi-implantable and implantable and the expected evolution according to the goals: replace, restore, enhance, improve and research. Image credit: BNCI Horizon 2020

The connection of our brain to a computer was in a way imprinted in the name that many gave to the earlier ideas of computers: "Electronic Brains". If they are both "brains" it makes sense to look for a connection among them: easier said than done. An "electronic brain" is a fixed thing with some hooks you can use as Input / Output gateways. That is what we use to connect a keyboard, a printer as well as other "electronic brains". Software will then take care of making out sense from the signals received through the gateways and will make sure that the signals sent out may be understood by the receiving party.

Our brain connects, as well, to a variety of peripherals through "nerves" and one approach would be to establish a connection with these nerves as entry/exit points. However, although this is done in some cases (like the artificial retina - see figure 57- or the artificial ear in the computer to brain direction and in the case of some limb/hand prosthetics in the brain to computer direction) BCI aims at a direct connection from the brain to a computer and viceversa.

This is quite tricky since there is no connector "inside the brain" and one needs to monitor the brain activity, in terms of neuronal activation, to extract a signal (in the brain to computer direction) and influence the activation of neurones in the computer to brain direction. There is no single neurone that can be associated to a signal nor a single neurone that can be activated to influence the brain in a given way. More than that: the variety of neurones whose activities defines a "signal" (or that have

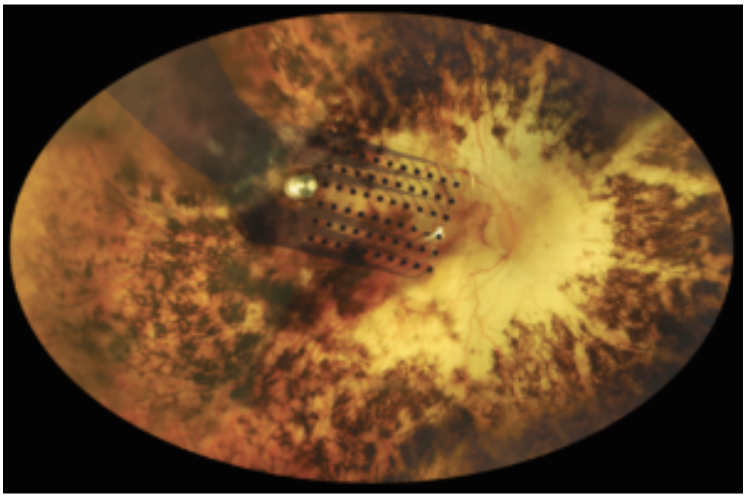


Fig. 57 An example of computer to brain connection via nerves. Argus II implant on a "blind" retina stimulates the optical nerve allowing the brain to perceive the light that hits the sensors on the implant.Image credit: University of Michigan/ Second Sight Medical Products

to be triggered for creating a signal) may be located in different parts of the brain and just to add complexity to complexity the set of neurones involved in an activity may (and do) change over time.

Hence, a connectivity like the one established between a computer and its peripherals is simply not possible. To get a signal from the brain we have to "look" at its global activity and "guess" what is going on. It is a bit like a car than to get a signal of the intention to turn from the driver, rather than being connected to the driver intention through the steering wheel, would have to rely on observing how the driver moves his eyes, some tell-tale signs from the mimic of his face and interpreting his voice message (assuming that he is saying something relevant at that particular point). Wouldn't that be a desperate endeavour?

Yet, this is exactly what researchers have been doing to extract a signal from the brain to be used by a computer. The really amazing thing is that they are succeeding!

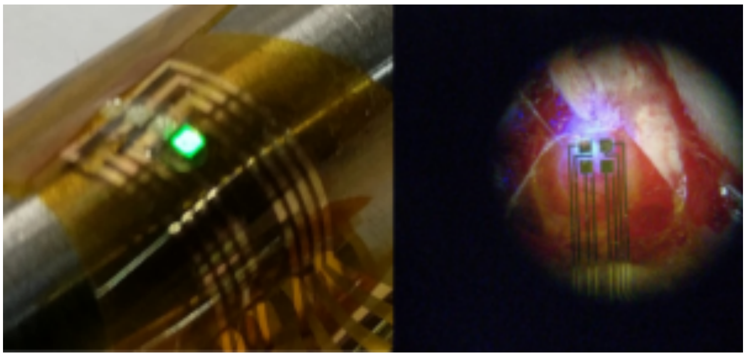


Fig. 58 Micro LEDs were used to optically detect seizures. The flexible optical device is shown on the left with a green-emitting LED. The photo on the right shows the device performing seizure detection on a rat's brain. Image credit: FindLight

The brain's electrical activity can be captured through sensors placed on the skull (non invasive sensing) or placed on the cortex or in the brain (in both cases surgery is needed). Recent technological advances are enabling the placement of multiple sensing points and the transmission of the detected activity using a wireless connection. Obviously, the closer the sensor is to the area generating an electrical activity, the less noise in the signal and the more precise the measurement. However, no-one would be looking forward to an invasive procedure so this is done only when strong medical reasons are present, like in the case shown in figure 58 of a patient suffering from epileptic attacks. Detecting with higher precision and sensitivity the insurgence of a condition that would lead to an epileptic attack allows the establishment of counteractions that avoid the attack.

In pursuing the goal of tackling disabilities (not just epilepsy, also Parkinson, dementia...) researchers are perfecting existing technologies and exploring /creating new ones. The convergence of material science (to create better sensors -graphene seems a good candidate, tinier and biocompatible with multi sensing capabilities), of artificial intelligence, in particular machine learning for better signal processing and even of robotics (for accurate placement of sensors in the brain) is expected to lead to significant progress in this decade, supporting the claim of this Megatrend for much better BCI. Progress in signal processing and machine learning will compensate for the lower signal precision provided by non-invasive BCI and this will expand the trials (today, as noted, limited to persons having very strong medical reasons that require brain surgery).

The way to go is still very long and full of obstacles: when we hear today of computers (robots) that can be controlled by the "mind" of an operator (like a paralysed person that using a BCI can control a robotic arm or a wheel-chair -watch the clip) we are implicitly led to believe that the computer can read a person's mind. This is not the case. What really happens is that that person has been training his brain to generate a specific electrical activity that can be interpreted by a computer and thus results in a specific action controlled by the computer. True, there are sensors that pick up this electrical activity but it is the person that, through training, learns to generate that electrical activity. On the computer side signal processing and machine learning identify that specific electrical activity among many others that are running in parallel and uses that as the input to start an action. In a way it is more the human brain learning how to control a computer than the computer learning what the human brain is thinking!

According to this Megatrend, in this decade there is the possibility of having a computer starting to understand some basic "intention" of a brain through machine learning and training (of the computer), but this is nowhere near having a computer that can read our mind!

There is also another big hurdle to overcome. Each brain is unique in terms of electrical activity (to the point that this can be used to identify a person, a digital signature of that person) and even more, this changes over time. Hence, a computer that can understand a person intention to move a wheelchair, will not be able to understand a different person having the same intention. BCI are, and will remain for the foreseeable future person specific. You can move the software from a computer to another so that a new computer can interface with that person but you cannot have that computer understand a different person (unless you start from scratch the training on the new person).

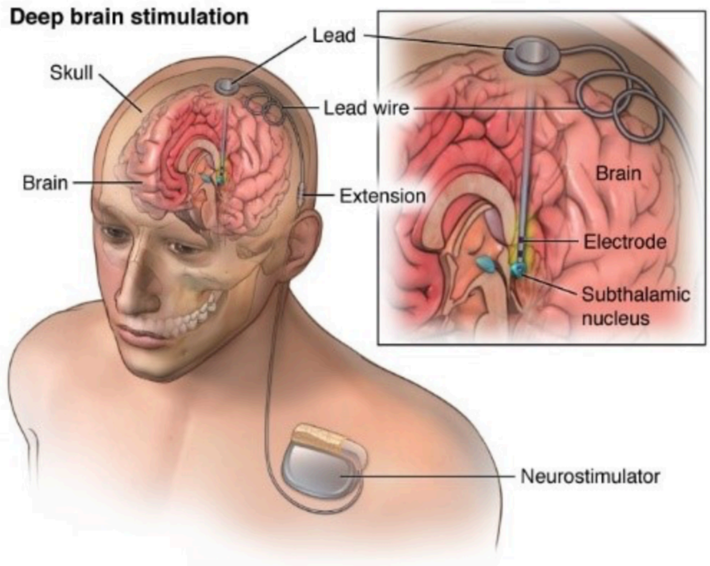


Fig. 59 Schematics of a Deep Brain Stimulation system using implanted electrodes controlled by a computer implanted under skin. Image credit: National Institute of Neurological Disorders

It will remain easier for a computer to read our "mind" in terms of mood and feelings, by looking at our face, analysing our voice and our speech than by analysing the electrical activity of the brain.

So far I just considered the brain to computer interface. The reason is because if this direction is difficult the other is close to impossible given today's knowledge and technology.

The computer to brain communications today results in a coarse induction of some physiological response, such as the already mentioned blocking of an epileptic attack. Here an electrical current is sent to some areas of the brain where anomalous electrical activity has been detected and this artificial current overwhelms the ones generated by the brain leading to a reset (it is not that different from the use of a defibrillator to block anomalous heart electrical currents: the one generated by the defibrillator is stronger and leads to a reset of the hearth own currents). More recently Deep Brain Stimulation (by inserting electrodes in the brain or by focussing beams of wireless energy in a certain spot in the brain) has been experimented to relieve certain symptoms of neurological disorders.

Technology evolution is now making possible to send signals to single neurones or to group of neurones using optogenetics, but so far this has only been used on animals and the goal is to have a way to study how neurones operate to express a given brain function, i.e. it is not used to transfer information to the brain.

In this decade, by some called the decade of the brain, there is strong expectation to break the code of the brain, i.e. to understand its way of working and that might lead in the future to better cure of neurological disorders. Personally I think that the dream of downloading information on a brain (who hasn't dreamt to learn by plugging in a flash memory rather than spending long hours studying...) will remain a dream for the foreseeable future.

*17. **Hi-Res VR in Retail***

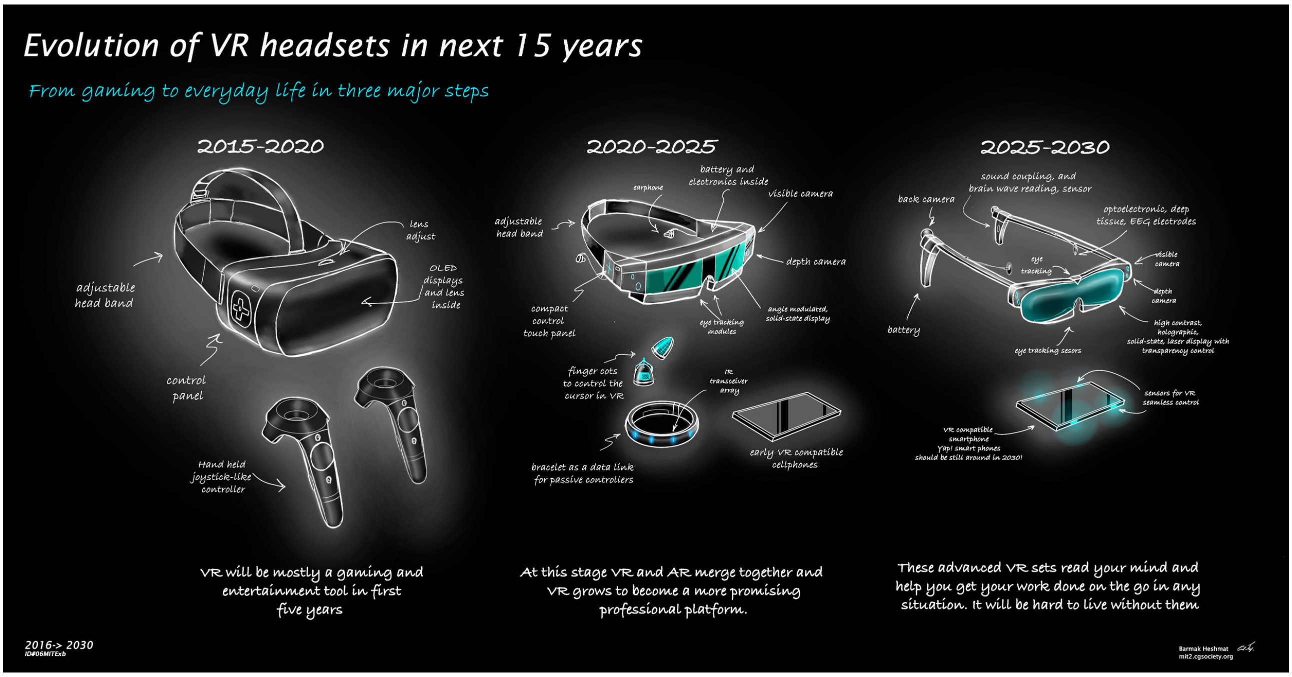


Fig. 60 Expected evolution of VR goggles in this decade. The graphic was drawn at MIT five years ago to cover a 15 years' span. It is still valid today, although, in a way, we are lagging a bit behind the foreseen roadmap but it may pick up steam in the coming years and deliver by 2030 what was expected. Image credit: Barmak Heshmat

VR - Virtual Reality- and AR - Augmented Reality- have been the talk of the town for quite a while. In the beginning the focus was on VR, the possibility of exploring with our senses virtual worlds in an immersive way to the point that we would feel to be part of those worlds.

Technology was not mature enough to deliver because of :

- bulky devices that kept you tethered to a machine

- grainy resolution that was delivering an image different from the ones we are used in the real world
- insufficient processing power resulting in low frame rate

As we look at this decade we can be sure that processing power will no longer be a stumbling block. The new chips, like the most recent ones from Qualcomm Snapdragon 888 to become available in 2021 or the ones powering top of the line smartphones, like the Apple A14 Bionics - faster than the 888 in early benchmarks- , promise sufficient power to drive high frame rate and high resolution plus local computation for local processing of sensors data. Notice that these chips when inserted in a headset can use cooling fans so are not constrained in extended peak performance as they are when used in a smartphone. Is current processing power sufficient for VR? Not yet, but in a few years it will be.

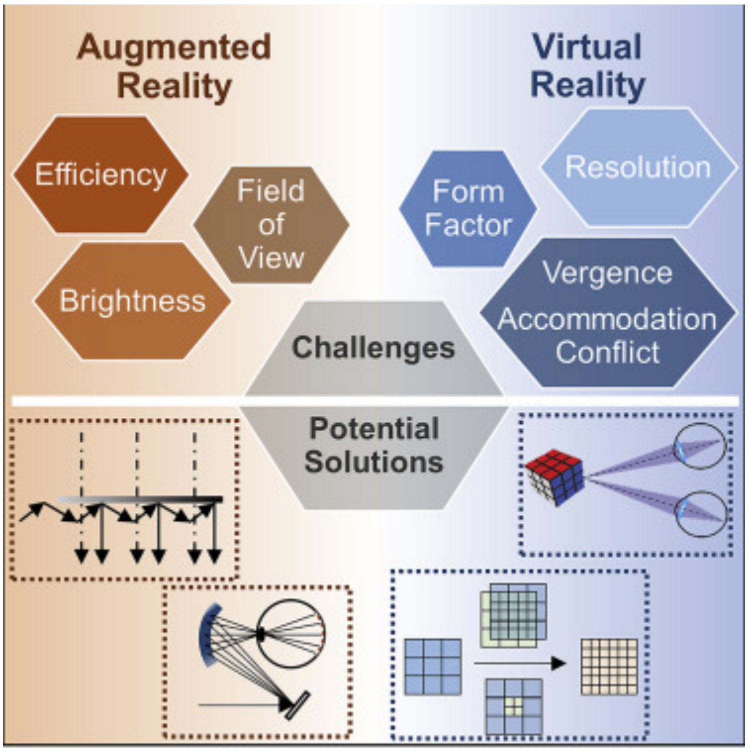


Fig. 61 A graphical representation of the challenges faced in VR and AR devices and the areas of research looking for solutions. Notice on the upper part the VR issues of form factor, of resolution and the problem of vergence -the attempt by the eyes to focus and manage near vision, whilst on the AR side the ones of brightness, efficinecy and fieldof vision - the form factor is also crucial for AR. Image credit: Tao Zhan and others, iScience Volume 23 Issue 8

In terms of resolution we have plenty of 4K screens and a few 8K are now available. However, one thing is to have a 70" 8K screen, quite a different story is to have that kind of resolution within a very small screen, such as those that have to fit in a headset. Here what really matters is the pixel density (like in a smartphone), and top of the line smartphones have exceeded 400ppi -pixels per inch-: the newest iPhone 12 has 476 ppi (the mini), the number one is the Sony Experia with 643 ppi. This kind of density is great (possibly already an overshooting for what is perceivable by our eyes in a smartphone) but are not sufficient for a headset, considering the very short distance of the eye from the screen. There are, however, concrete promises for technologies delivering much higher densities, like the one spearheaded by MojoVision, a Californian start up focussing on ultra high density displays for augmented reality devices. Their latest screen has the size of a grain of rice and a density of 14,000 ppi! So, on the resolution/ density side we can be confident that technology meeting the requirements will become available in this decade. However, the perceived quality of an image involves more than resolution. It is also about brightness, contrast, ... Most important it is about the possibility to be in focus. Here the problems remain significant. The fact is that with television/computer and even smartphone screens it is our eyes that take care of focussing but when the screen is just a few cm, less than one inch, away for your eyes, as in the case of a headset, focus is not possible.

New approaches are needed where it is the screen that has to take care of focussing the images on our retina. As shown in the clips (if you are interested in this subject, they are worth the 20 minutes it takes to watch them) there are a few technologies that might be used but it is still a research areas. So far, no silver bullet has been found, yet this area is crucially important because it is the bridge between the resolution/density problem and the form factor problem.

Indeed, the form factor problem remains, and will remain, the main hurdle to meet the requirements for a seamless VR in this decade. Notice that, in addition to the issues I mentioned there are some more fundamental aspects of perception that are very difficult to resolve given the current technologies and the ones we can foresee in the coming decades. Our perception of reality has been chiseled into our brain through evolution as a species and in the first years of our life. As an example, we expect a small beads to be, and feel, lighter than a bigger one. When this is not the case a red flag is raised to draw our attention to the issue. If you pick up a hollow bead looking like made of steel, and a smaller one made with lead the smaller one will feel much heavier and this would seem strange. This is just to emphasise that our perception of reality is derived from a multi-sensorial experience coupled with expectation. The VR will eventually be able to deliver credible sensorial experience in terms of vision and hearing, but it will fall short in terms of those sensations derived from proprioceptors (the sense that tells our position in space and acceleration - perception of movements). Pilots training at professional flight simulators enters a simulated space that provides -up to a point- movement and acceleration sensation but this uses a very complex machinery that clearly cannot be part of an everyday VR experience.

BCI might, in the very distant future, trick the brain into a full sensorial virtual reality but so far it is still in the science fiction domain.

Fig. 62 AR and VR are already been “tested” in shopping malls as a new way to have offer meet demand and as a tool for customisation of the offer. Image credit: Hackernoon

A different story is looking a some specific application of VR, such as the claim in this Megatrend about a revolution in Retail and real estate business.

In this market segment both VR and AR have already carved a dent in the marketing of products (and estates). It is now pretty common to see a 3D space that can be explored to get a feeling of a house, an apartment. Similarly, AR is being used by some department stores on the web to give you a feeling on how a given product would look like in your home (the Ikea app is a good example).

Even the pandemic is accelerating this shift. We have become familiar using QR codes (a very old hat) for exploring menus and catalogues to avoid interaction with physical objects. Most important we have learnt to explore "reality" using augmented reality and virtual reality. This is a crucial paradigm change in terms of perception.

According to this Megatrend AR and VR will become an integral part of our daily life when buying on line. Thinking about buying a new dress on line? This is not usual today, what if it doesn't fit, and even if it will, how will it look on me? Here comes VR and AR. Your avatar, embedded in and shared by your personal digital twin will connect to the retailer and through virtual reality you'll be able to look at yourself like in the mirror of a shop, to turn around and see how the dress fits and looks. Your size, and shape, is exactly mirrored in your personal Digital Twin, hence the rendering will be accurate. Want to check how the tie you bought last month will go along with that dress you are (virtually) donning? No problem. A quick selfie if you are wearing the tie right now, or a snapshot at the tie and you can see it through virtual reality along with the dress you are (virtually) trying on.

Likewise, if you are considering buying a new house you may want to see how your current furniture would fit and look in the new house. Let the digital twin of your current house interact with the one of the prospective house and through virtual reality take a walk around the prospective house and get the feeling.

The convergence of new devices (with the smartphone probably taking the lion share) with artificial intelligence, digital twins and the digitalisation of products and ambients makes this Megatrend credible. Do not expect, however, that by the end of this decade virtual reality will feel like the physical reality. I don't think we will be there for quite a while.

*18. **Focus on sustainability and environment***

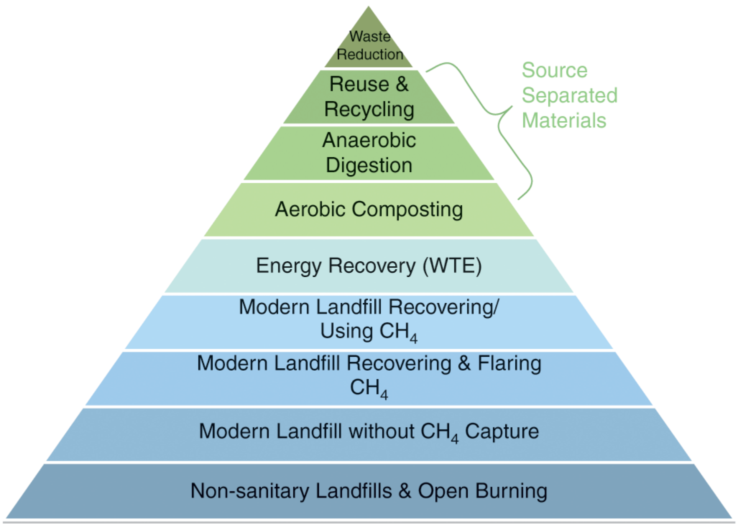


Fig. 64 The [pyramid of solid waste management]() from the bottom where waste is disposed in the environment without any precaution to the top towards reuse/recycle and decrease of waste. Image credit: Stelios Grafakos

Natural resources have been out there to grab and once they were no longer needed (nor the resulting craft they resulted in) they were discarded in the least costly way. The emergence of an environmental awareness and of a sustainable use of resources is relatively recent. Notice that our ancestors run several times into resource shortage and they moved looking for a place of plenty (or at least of some!).

It should also be noticed that only 200 years ago there were one billion people on the planet, one seventh of today ([for curiosity](), the human population was estimated between 200-300 million 2,000 years ago, and it remained stable for a thousands years (310 million estimated in the year 1,000, triplicating in the following 800 years, duplicating in the following one hundred years and triplicating in the last 100 years).

However, what really impresses me most is that looking at the pro-capita use of energy we get an astounding fact: 1, 000 years ago, till the beginning of the industrial revolution, on average people used pro-capita basically the same amount of energy we use today! It seems impossible, doesn't it? Think about cars, electronics, food packaging ... it really seems unbelievable. Yet, [that is the case]().

A thousand years ago the energy used (for a physicist the power used) derived from (percentages are an approximation hence total is not 100):

- 50% animal traction (like the ox pulling a plow),
- 25% wood,
- 12.5% water,
- 5% human,

- 2% windmill,
- 1% sail

One thing that is evident is that till 300 years ago people were using renewable energy! However, using renewable energy does not mean that it is sustainable. Many islands in the Pacific Ocean were abandoned after the depletion of forest, the source of wood energy.

How can we explain the fact that our ancestors were using, pro-capita, as much energy as we use today, yet doing a fraction of what we do? The key is efficiency, or if you want "inefficiency". Using an ox to plow a patch of land is much more energy hungry than using a tractor! You have to feed the ox and you have to feed it whether it is plowing or not. Heating a house using a fireplace and a chimney is not energy efficient at all (most of the heat goes up in the sky. Pre-Industrial Revolution Europe is estimated to have used some 15GWh of power and if you scale it up for population and GDP you get at pro-capita that is equal if not greater than today's use of energy.

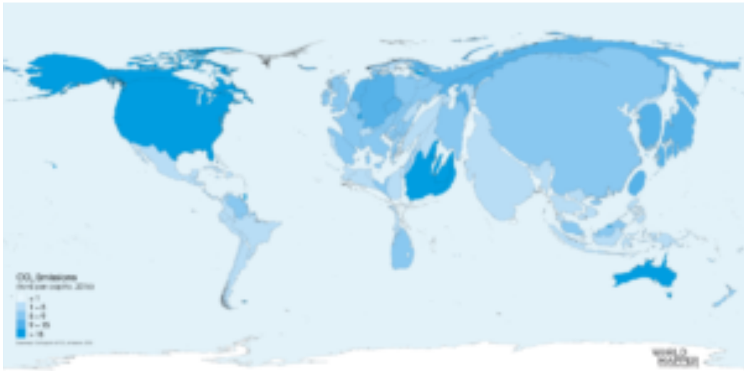


Fig. 65 A distorted map of our planet where each region size is proportional to the pro-capita emission of CO2, a good yardstick measuring the use of power (in 2016). Image credit: World Mapper

I am telling this to make the point that when talking about sustainability and environment we need to look at the big picture and in the big picture the use of renewable energy is not necessarily resulting in sustainable processes, nor it is necessarily environment wise. Efficient use of power is as important as the source of power.

Indeed humans in the past systematically destroyed local resources and had to move somewhere else because of that. What is different today is that humankind having occupied the whole planet has no place left to go! Additionally, today we are relying for a significant portion on non renewable energy sources (at least not renewable in the short term, knowing that there will be brand new oil available 400 million years from now does not help!). What is different today is that rather than 300 million there are now over 7 billion people, 25 times as much, people that are transforming resources into waste. Hence we have problems both on the resource side (provisioning) and on the waste side (disposal).

The environment is affected on both sides: the provisioning of resources impacts the environment (mining is one of the most polluting industry) and waste is obviously impacting the environment.

Technology has been a double edged sword: on the one hand it has greatly improved the efficiency of power use (as mentioned we do so much more today than a thousand years ago, yet we are using, pro-capita, the same amount of power) but on the other hand technology is directly and indirectly power hungry: directly because we need huge amount of power to "manufacture" our wellbeing (like building a car) and a huge amount of power to enjoy our wellbeing (like using the car). For the record, producing a car requires an equivalent of 1,000 litre (260 gallons) of gasoline (manufacturing an electric car requires 1,250 litre - that's 25% more because of the batteries); using the car ... well it depends how you use it. In my case I use some 500 l per year, over the 10 years of the car life that is 5,000 litres, 5 times more than manufacturing it. Interestingly, in terms of carbon footprint (CO2 emissions) the production is equivalent to the use of the car throughout its lifetime.

The carbon footprint of an electric car is some 25% higher than a combustion engine car for manufacturing **and** disposal, whilst the carbon footprint of its usage depends on the way the electricity used to recharge the batteries is produced. Unless this comes from renewable and zero footprint sources an electric car has a higher environmental impact in terms of CO_2.

This Megatrend is foreseeing a strong increase in general awareness on the importance of sustainability and environment protection, hand in hand with technology evolution decreasing the cost of managing sustainability along the value chain (from design to recycle/disposal). Last, but not least, this Megatrend foresees growing biz opportunities of an ecosystem that can transform waste in revenues (at least part of it). This is not that different from what happens in Nature where the waste in a food chain becomes the thriving ambient of an ecosystem of smaller animals, plants and, most importantly, bacteria. How could this be? Isn't this against the second law of thermodynamics? Well, there is a trick, and that is tapping energy outside of the system (the Earth) to decrease, locally, the entropy: tapping the Sun energy. We are probably going to do the same, using Sun energy using low cost tech to power the sustainable value chain.

19. CRISPR and gene therapy to fight diseases

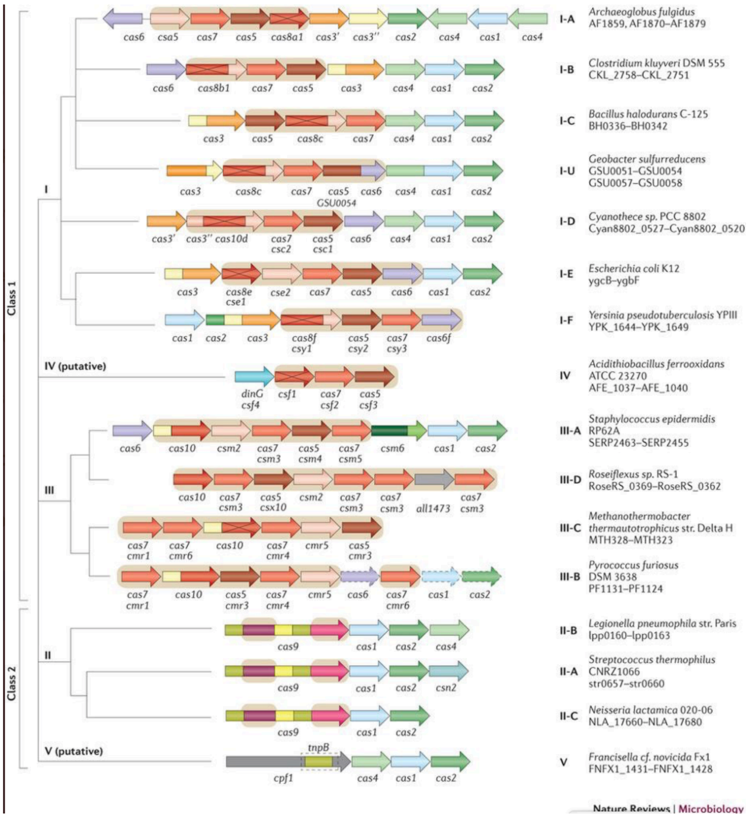


Fig. 66 Class 1 and class 2 CRISPR-Cas systems. The growing varieties of CRISPR-CasX are providing more specific tools to researchers, and in the latest part of this decade will provide tools to practitioners, for manipulating DNA and RNA.
Image credit: Eugene Koonin, NatureEcoEvo, feb.2019

CRISPR - Clustered Regularly Interspaced Short Palindromic Repeats- is a series of DNA chunks discovered in bacteria in the last decade of the XX century. Researchers found out (a bit later) that these were remnants from bacteriofagi (nasty bits that eats bacteria from the inside, even bacteria get sick!) that infected bacterias and where killed by the bacteria reaction. The killing resulted in a sort of immunity (the bacteria got vaccinated) so that if another fagi invaded the bacteria it was recognised and duly killed using a protein associated to the DNA sequence Cas - CRISPR associated protein. The “killing” is done by breaking the DNA of the fagi, basically it works like e scissor). There are quite a few of proteins that can be associated and scientists decided to call them with a number.

They also discovered that a particular protein, Cas9, was pretty good in the editing of a DNA string in vitro and started with experiments. After a while they realised that CRISPR-Cas9 can be used as a tool for gene editing and a whole new slate of possibilities opened up (the 2020 Nobel Prize in chemistry was awarded to Charpentier and Doudna for their contribution is establishing this technique).

As shown in the graphic in figure 66 (click on the link to get a readable size), CRISPR-Cas9 can be used, as bacteria do, to kill a "gene" by chopping the DNA strand at the point where that gene is contained. The cell will patch it up stitching the broken strands together but in doing so it will lose some parts of the original gene, thus disabling it. However, CRISPR-Cas9 can also be used to insert a new chunk of DNA as a replacement of the disabled gene. In the previous case the cell will no longer be able to produce a certain protein (and that may be good if that protein was creating problems, as it is the case in some genetic disorders) whilst in the latter the new gene can provide the instructions needed by the cell to produce a protein (again, some genetic disorders derive from the inability of cells to produce a certain protein).

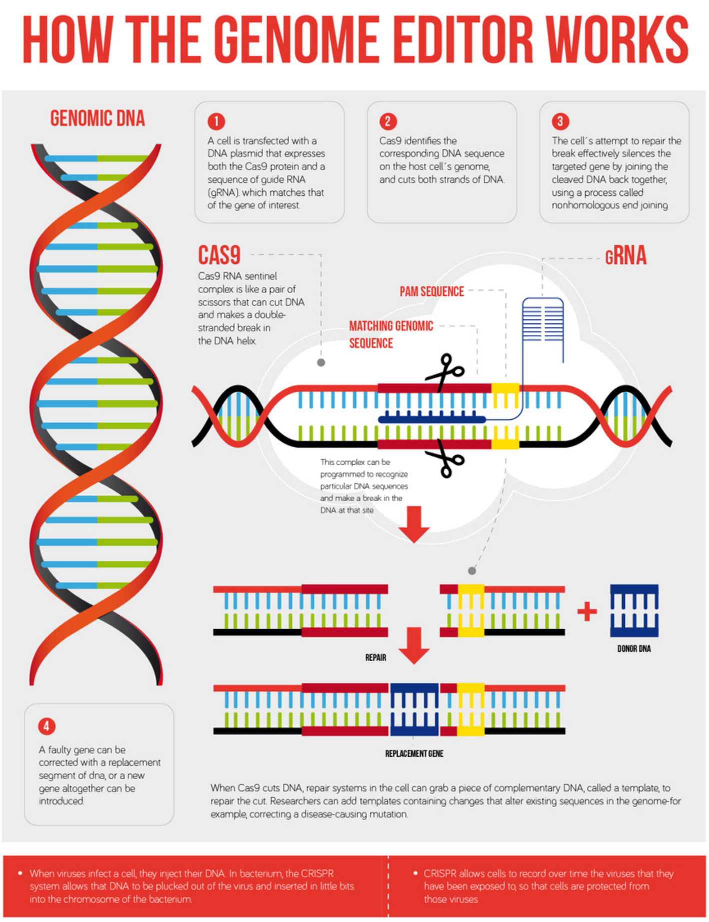


Fig. 67 Schematics showing how CRISPR-Cas 9 work in silencing a gene (by cutting the DNA location storing that gene - the cell repairs the break but the gene is not restored so it remains inactive) or in inserting a new code -a new gene- in the DNA strand. Image credit: Freelancer

In practice, scientists now have a tool, CRISPR-Cas9 allowing them to manipulate the DNA to get a specific result. As in anything having to do with biology (differently from mechanics) the process has a statistical flavour. On the average you get the result you are looking for but there are cases where this is not achieved, where the cut is not occurring where it was planned or the insertion does not work out the way you wanted. However, as long as the majority of the operations have a positive result you are good (not all cells, as an example, will have the capability of manufacturing that protein but if a sufficient number will the genetic disorder can disappear).

This lack of absolute precision is also the ground for several scientists and ethicists to object on the procedure. By altering the DNA of a living being you may set up a clicking bomb that could lead to unexpected consequences (one of the issue here is that we don't know how the genotype - the instructions contained in the DNA strands- results in a phenotype - in the actual living being and its behaviour. A single gene is often involved in many traits of a living being and conversely a given trait my involve several genes and the truth is that at today's level of knowledge we do not know the relationships (or better, we understand just a tiny fraction). Hence the opposition to modify the code of life - better be cautious than sorry.

On the other hand, it is evident the potential advantages that this technology may offer, starting with, obviously, the cure to genetic disorders (there are some 6,000 known today). Once perfected (i.e. becoming more accurate and predictable) could also be used to improve a living being (this is something that occurs in Nature over million of years of selection process and that science can make possible in e few weeks...). We have already seen this technology applied to create bacteria with specific characteristics (like the capability to adsorb heavy metals to clean up a polluted area). Here again we are faced with a Pandora's box: once we open the lid of genetic modifications the possibilities are huge but are we sure we want to live with all the consequences (and who is going to decide what is right or wrong)?

The CRISPR-Cas9 has proved to be a practical tool, the first technology available for genetic modification but in the last ten years several others have been found, each one having specific characteristics that would make it useful in a given application. Also, scientists have discovered a way to apply the genetic modification to the RNA, rather than the DNA. This is somehow better since the modifications will not propagate to the offsprings, therefore limiting the concerns (although not completely clearing them). A person with a genetic disorder may be cured through RNA modification but that will require continuous intervention since the new cells (and we keep changing our cells) will be affected by the disorder since their DNA has not been changed/fixed. Additionally, the baby born from that person will have a chance of inheriting the disorder. Hence in case of genetic disorders a DNA modification is the way to go. In case of "augmentation" using the RNA path would probably be better.

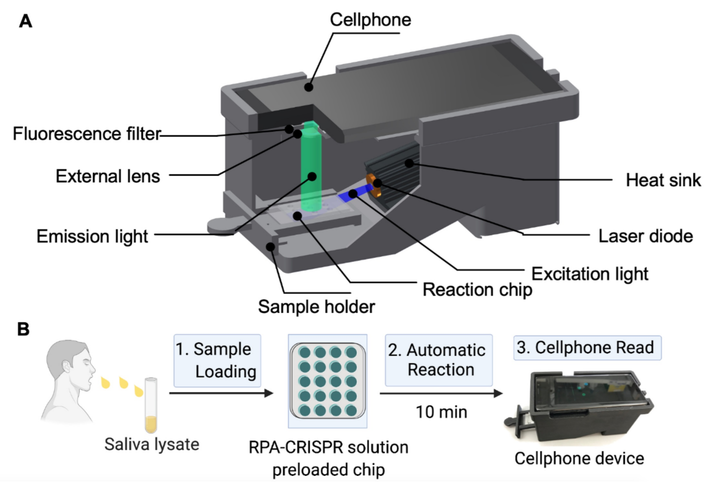


Fig. 68 A smartphone-based COVID-19 test developed at Tulane University's School of Medicine uses CRISPR to detect coronavirus RNA in a saliva sample within 15 minutes. Image credit: Bo Ning et al

CRISPR can also be used as a sensor and a team of researchers at the Gladstone Institute of Virology have developed a test, that is awaiting for FDA approval, that uses it to detect with high precision the presence of the Covid-19 virus. Interestingly, the test has been designed as do-it-yourself so that people can run it at home, by picking up some saliva from their mouth. Interestingly, as shown in figure 68, part of the processing takes place in a micro-fluidic chip connected to a smartphone, in charge of the heavy computation and display of result.

This Megatrend is foreseen that progress will continue at a fast pace throughout this decade and will result in cure for hundreds of genetic diseases by the end of this decade.

20. The vanishing Babel tower

This Megatrend, as the following ones, is mine and expands the list of the Megatrends I discussed in the previous sections as proposed by Peter Diamandis. It is about technology overcoming languages barrier.

There are roughly 6,500 languages spoken in the world today, although most of them are very "local" and on the way to become extinct. Although in the past there were fewer people, more languages were spoken, since communications was more difficult and each small community drifted over time differentiating its language from the ones of surrounding communities. Of course also in the past there were some sort of common languages, in Europe 2000 years ago it was Latin and (ancient) Greek.

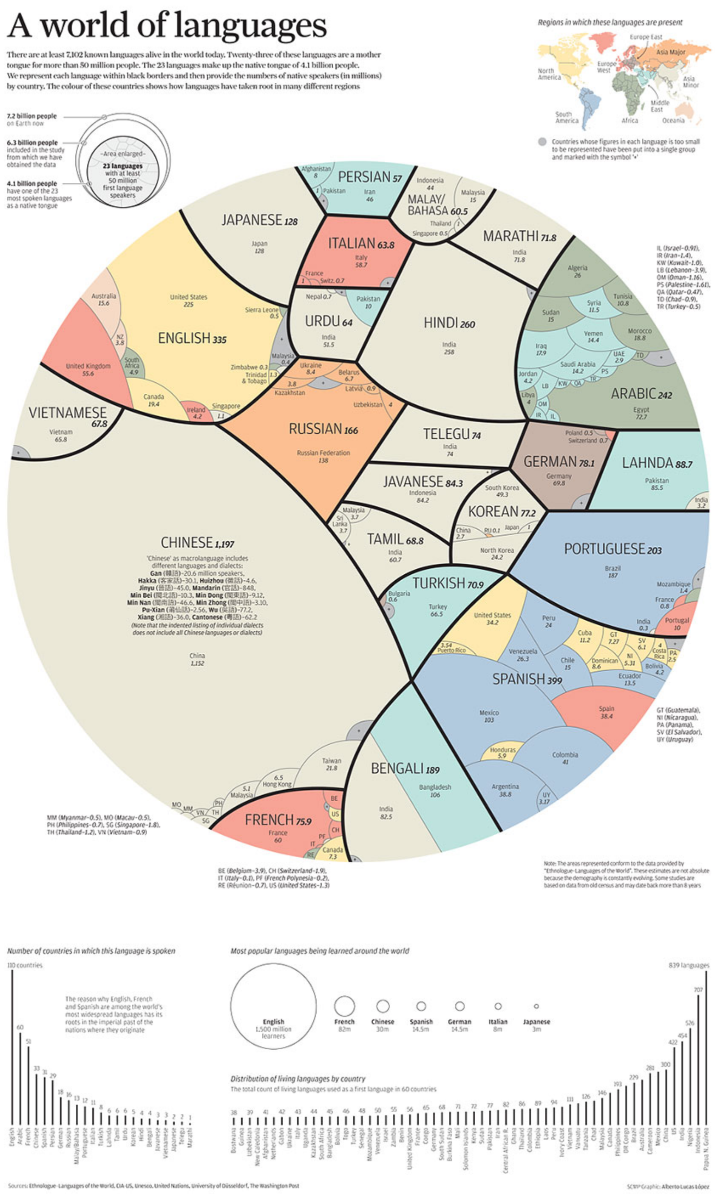


Fig. 69 The top 23 most spoken languages in today's world. Notice that English, as an example, is counted as a single language although there are several variants. Image credit: InLingua, data source: Ethnologue Languages of the World - Click for the [expanded - readable map](#).

Marco Polo, in his famous report of his voyages to the Cathay, tells us that he learnt new languages on his way to meet the Kublai Khan: Turkish, Arabic, Persian and Mongolian (he didn't speak Chinese since the Kublai Khan spoke Mongolian) but it took him 4 years to travel from Venice to Beijing, plenty of time to learn a new language (a today's Marco Polo will cover the distance in about 10 hours, tricky to learn 4 languages in that short time).

It is the quick pace of modern life, the presence of tons of literature written in different languages and the frequent movement of people that has created a real Babel Tower: for the ancient the difference in languages was not a big deal (at least for the great majority of people).

I remember when I was a kid (long time ago) my father telling me that in the world I was to live knowing a foreign language would have given me a competitive edge (and he sent me to study German in Switzerland...).

Now a foreign language has become part of most Countries high school curricula, and in quite a few it is even part of primary school. Unfortunately we learn different "second languages" in different parts of the world with the result that I am usually lost when I want to communicate with local folks on the other side of the planet.

However, the situation is changing and this is the point of this Megatrend: early this year I was in Laos, in the countryside and Laotian is quite a different piece of cake from Italian. Some elderly people spoke French (and that was good), several young people spoke Chinese but that was it (and this latter dod not help me). We did manage to establish some form of communications through our smartphones: we typed in an Italian sentence and showed the other party the translation in Laotian, courtesy of Google. I cannot tell if the translation was good or bad, but I can tell that it worked. We were able to communicate.

That was amazing, but it is nothing if compared to what I feel will be possible by the end of this decade: talking in one language and having the other party listening in her language (and vice versa).

Real time translation is becoming state of the art. Google is now offering free translation to < > from 108 languages, a tiny fraction of the 6,500 spoken in the world but covering basically all the world. The latest addition were:

- Kinyarwanda,
- Odia,
- Tatar,
- Turkmen, and
- Uyghur

and I have to confess I didn't even know they existed, yet Google stated that they are spoken (in total) by some 75 million people. I routinely read articles in Chinese, just by cutting and pasting the text into Google Translator and reading the English version and I know many people doing the same, every single day. Language differences are no longer a barrier.

I find this amazing and I bet that by the end of this decade I will be listening through my wireless headphones to the other party with that language converted, seamlessly, in my language. That is a game changer.

Think about what this will mean for tourism. Not just to you as a tourist, but -more important- to local people in a far away place that will be able to offer you services and experiences, and we know that tourism is evolving in this direction. There are now many Local Guides and the web is connecting them to the world.
Add to this that by the end of this decade virtual reality will enable to experience many places from our living rooms: we will be able to experience a walk in a souk in Istambul and talk to local people in Turkish, then flip to the souk in Marrakesh and talk to the spice sellers in Arabic. The possibilities are endless and they will change what we mean with tourism.

I am not saying at all that we will be staying home (I hope the pandemic will be over!!!), just that from home I will be able to get a taste of the experiences that I will have (or that I had).

When travelling we will be using this possibility even more, through augmented reality, where the augmentation takes the form of sound, hearing people speaking our language in spite of the fact that the origin of the sound was in a different tongue.

To me this Megatrend is the one that is most likely to become reality, and it is also one that will have most impact on feeling part of a single planet.

*21. **Healthcare in the Cyberspace***

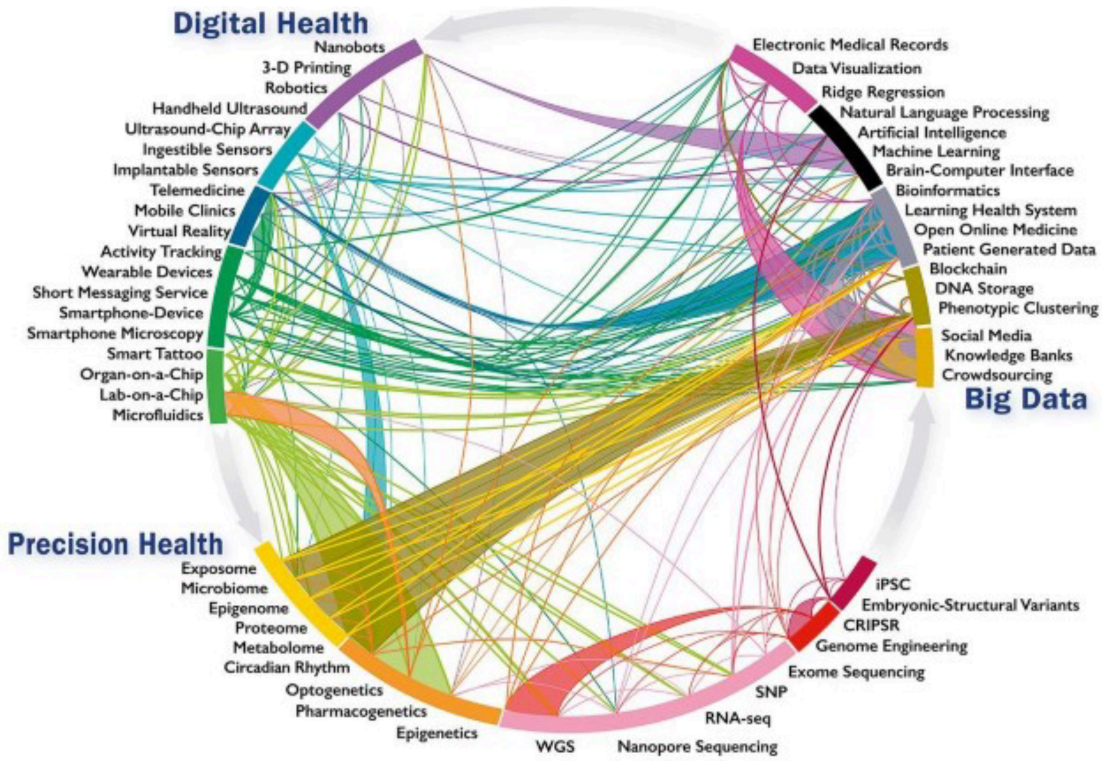


Fig. 70 A representation of the three main pillars for future innovation in healthcare: Digital Health, Precision Health and Big Data. The graphics shows pretty well the correlation among these three pillars. Image credit: ACC - American College of Cardiology

This Megatrend is likely to land in slightly different ways and at different pace in different Countries (and regions within a Country) but I consider this as unavoidable under the pressure of:

- steady increase of pro-capita healthcare cost
- availability of better cure / preventative cure that are considered as part of the basic human rights
- change in paradigm: from exams for diagnoses to exams for curing

as well as sustained by:

- ambient, wearable and implanted sensors
- EHR - Electronic Health Record
- personal digital twin
- body on a chip
- artificial intelligence
- Chatbots

All of the above is being accelerated by the 2020 pandemic. In fact, the shift towards a digitalisation of Healthcare goes back at least a decade and potentially it could have found broad application in the last 5 years but bureaucracy and siloed systems have retarded its implementation. The pandemic has put healthcare institutions under severe stress and, sometimes like in Italy, the cyberspace has been used as a digital crutch. As an example, all of a sudden, all Italians have shifted to the electronic prescription that originates from the family doctor upon a remote consultancy and goes directly to the pharmacy where we can pick up the medicine. The whole machinery was already in place but not used. The pandemic did in a week what has been attempted for at least 3 years. At the same time special support centres have been set up to evaluate Covid-19 symptoms and risks and, in many areas, at home testing and tele-support has been implemented. Furthermore, the data harvested from individuals and from institutions are being used to drive Government policy almost in real time (the changes to the containment measures have been so frequent to generate sarcasm and opposition: why did they keep changing their mind? The culture of people is still rooted in the past when it took ages to take a decision and even more to modify it). I believe that these changes are here to stay and will become the new norm by the end of this decade.

a) steady increase of healthcare cost

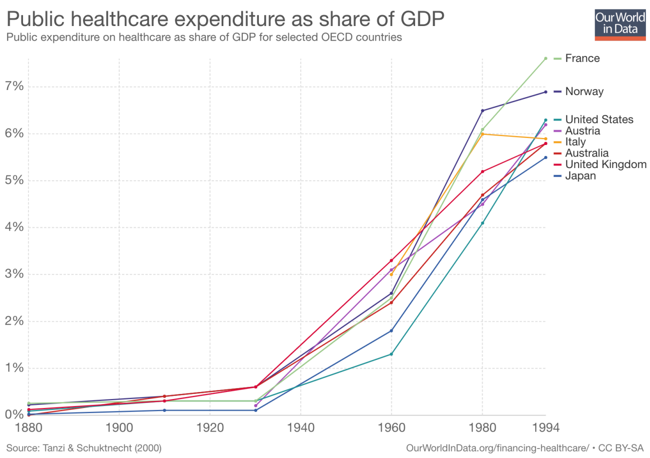


Fig. 71 Public health cost has increased everywhere, as shown in this graphic, both in absolute value and as % of a Country GDP. Image credit: Our World in data

Healthcare cost has increased dramatically in developed Countries in the last 50 years as shown in figure 71, both in absolute value and as percentage of the GDP and this trend is continuing today. As reported by Our World in Data, healthcare spending was a meagre 0.5% in the 1900 in the US (and the % was quite similar in many other countries) reaching 8.5% in 2014 and an astounding 17.7% in 2019 (3.3 trillion $, 11,582$ per person). And that was before the pandemic! The total cost (including GDP decrease, jobs loss, countermeasures) is estimated in 16 trillion $ for the US. The average cost for in-patient care for Covid-19 ranges between 51,000 and 78,000$ depending on patient's age. Vaccination for a Country like US goes into the tens of billions $.

Even without consideration to Covid-19, and the graphic is quite clear on this, healthcare cost have been on an accelerated rise in the last five decades and have reached a critical level where both Countries and single citizens can no longer afford further increase.

b) availability of better cure / preventative cure

Fig. 72 Various measures of preventative healthcare services for women. A similar graphic can be made for men. Image credit: Aeroflow Healthcare

Medicine has progressed enormously in these last twenty year, thanks to both science and technology (with technology in the driver seat, since science has progressed thanks to technology).

The portfolio of available drugs has increased, resulting in more efficient drugs and in drugs able to fight a broader slate of ailments. In parallel surgery and other medical procedures are able to address situations that just 10 years ago would have been impossible.

Prosthetics are becoming more and more effective in addressing disabilities but they are not cheap. An Argus II retinal implant (bionic eye) may cost well over 500,000$, a liver transplant also cost over 500,000$...

We have the possibility of mass screening, and focussed personal screening (the "check-up") and it is often said that the cost of preventative measures is way lower than the cost of cure. Hence, the interest of healthcare institutions to move towards preventative measures. To maximise the effectiveness, and minimise cost, preventative measures (like mammography screening, colon cancer test, prostatic cancer test, ...) target the higher risk population leveraging on statistical data.

c) change in paradigm

In the coming years of this decade we are going to see an increase in personalised cure. We already see this approach in preventing recurrence of breast cancer, in the cure of lung cancer. Exams are run to identify specific genes that can make the patient at a higher risk of recurrence, or other genes that can make a specific therapy more effective. Doctors are now prescribing exams to decide the cure, rather than exams to make a diagnoses. This is a change in paradigm and we are going to see this becoming the norm by the end of this decade. Precision Healthcare is the name of this new approach. Rather than using the "one fits all" approach doctors are looking for a therapy for that specific person. By the end of this decade we will have medicines that are so person specific that they will not be effective on a different person and because of that these medicines would not have been used for any other person. This changes completely the approach to the approval of medicine since we can no longer trust statistical data, that medicine has been designed for that person, there are no data on its effectiveness (nor on its side effects!). This will call for a completely new way of monitoring the patient.

The evolution of healthcare in this decade will be sustained by the convergence of several technology areas, each progressing independently from one another under the pressure of demand from several markets (i.e. these technologies are not healthcare specific):

d) ambient, wearable and implantable sensors

Fig. 73 The global wearable medical devices market is expected to grow to $67.2 billion by 2030, at a CAGR of 18.3% during 2020–2030. This forecast was made before the pandemic so it is probably underestimating the growth. Image credit: Prescient Strategic Intelligence

There are already millions of wearables in use that monitors some basic physiological parameters. The starting point was fitness but in the last three years data generated by wearable sensors have started to be processed to derive health indications. The Apple Watch has been the first mass market product to become certified for detecting a medical condition (atrial fibrillation) and the latest version can provide a simplified ECG that can be sent to the doctor for first analyses. Additionally trials are ongoing to detect movement disorders to get insights on the Parkinson disease. Wearable blood pressure sensors, position sensors, bio-sensors are becoming mainstream and will be a common sight by the end of this decade.

In addition to wearable sensors, ambient sensors will become an important source of health data in hospitals, offices and, most important, at home. In addition to the issues that have to be addressed with wearable when applied to healthcare, ambient sensors raise privacy issues that need to be managed, particularly when used in public spaces, like hospitals and offices. As for any other healthcare related data security, ownership and privacy are crucial (see next point) and it is obvious that data gathered in a public ambient, often with people unaware of what is going on, present even more problems.

Fig. 74 A self-adhesive biosensor to automatically and continuously measure vital signs, body posture and step count, and detects falls. Image credit: Philips

In the second part of this decade we can expect the rise of implantable sensors. Whilst the growth of health related wearable was driven by fitness that expanded into health, for implantable sensors the adoption will be driven by specific "need to have" like glucose monitoring for diabete patients. Implantable sensors are, obviously, invasive and require (limited) surgery. On the positive side they are fading away from perception and unlike wearables cannot be forgotten. Technology evolution promises extended life cycle through self-charging as well as creating sensors that once implanted in the body will work for a pre-defined period of time and then fade away by biodegrade in the body.
In all cases data communication from the sensors to the monitoring application takes place via local wireless network that connects to the service provider. Some data processing usually takes place locally, with the smartphone playing an important role (also as gateway) although most processing will take place in the cloud, managed by a healthcare service provider.
We can also expect that some medicine will embed IoT, sensor, to signal the "swallowing" whilst other biosensors will monitor the effect.

e) EHR - Electronic Health Record

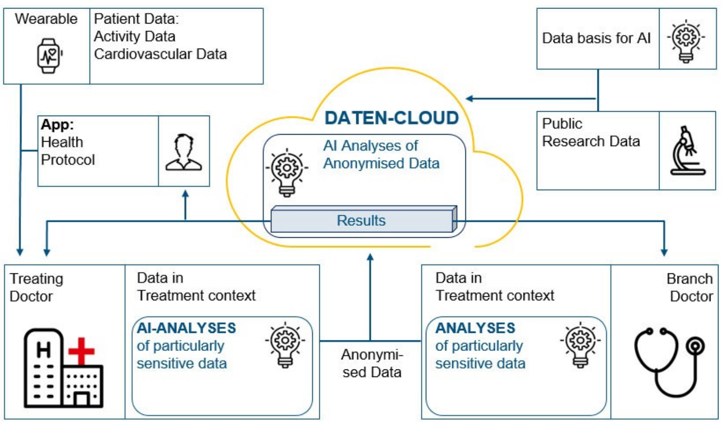


Fig. 75 Gaia X use case in the Healthcare domain. The diagram shows the management of data in the European Cloud. These data are generated by wearables, hospitals, medical testing and are used by the citizen via apps, by healthcare providers and by researchers. Image credit: Christian Lawerenz and Prof. Dr. Roland Eils, University Medicine Berlin

Electronic Health Records are becoming widespread in terms of concept and even in terms of regulatory framework but actual implementation and interoperability are still an open matter. The European Union has an agreed framework for the EHR and member states are required to implement it. The recent Gaia-X initiative should support this data framework and provide the required security measures. There are now a number of use cases in the Gaia X framework, see figure 75, to apply the EU framework to the healthcare area. Different frameworks, although having the same objective, are being implemented in the US, in China - Japan, Singapore, and many more Countries. Whilst some Countries are well on the way of full deployment and use of EHR, others are still in the early

deployment phase (or haven't started yet). By the end of this decade the penetration in the G20 Countries should be completed and interoperability shall be achieved. These Countries will steer the application also in the other parts of the world, although it is unlikely that a full deployment can take place within this decade. Based on a recent report from the WHO -World Health Organisation-, but based on 2016 data, the way to go is still long to achieve full coverage.
At the same time the pandemic has put a big pressure on both accelerating the deployment and revising the framework for the EHR.
The key point is the need to ensure an effective (accurate and prompt) flow of data across healthcare institutions (hospitals) across borders to detect early signs of an epidemic and provide effective control.
This extends to the personal data sphere, since a healthcare "passport" is becoming a key to enable safe travel across borders.
The EHR is also seen as an important tool to support research and to monitor drugs effects. By having a huge data set it becomes possible to use machine learning and data analytics technique to extract information from the global EHR. This has clearly important societal implications but it is also having huge business implication, hence the need to tackle data ownership issues.

f) personal digital twin

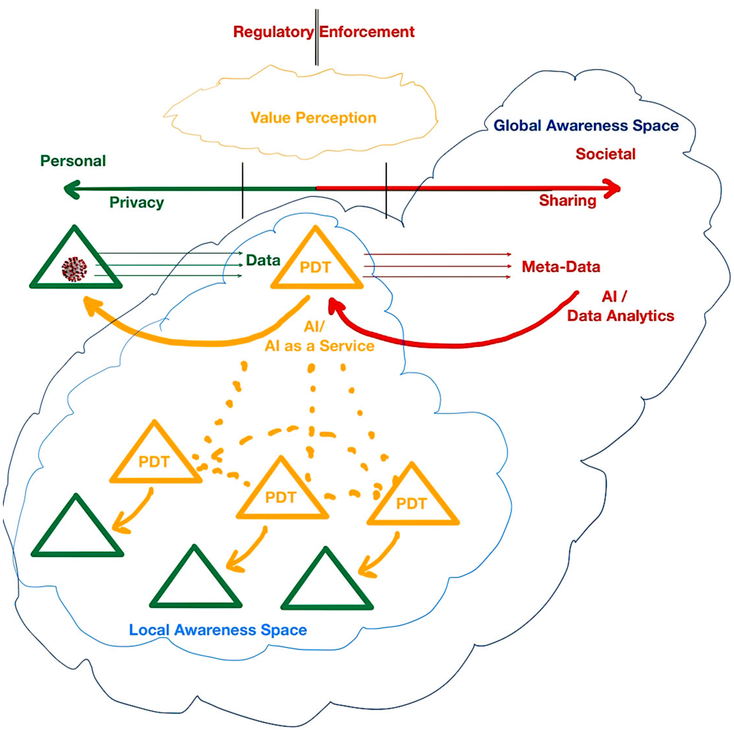


Fig. 76 Framework for using PDT in the context of the monitoring and control of an epidemic. A PDT act as a gateway separating the person from the context, thus preserving privacy whilst ensuring awareness on societal obligations. A PDT can autonomously interact with other PDTs representing persons that are within an epidemic risk radius, as shown in the lower part of the graphic. The local intelligence can therefore extend to a cluster of local intelligences and the emerging information is shared with the relevant institutions.

The data mirroring and recording the healthcare status/history of a person are part of the EHR of that person. New studies are ongoing to extract local intelligence from those data giving rise to a Personal Digital Twin -PDT- serving the healthcare space.
A PDT in the Healthcare space is connected to its physical twin in a variety of ways. First a framework can be defined (a regulatory framework could be used as background) and made available through a healthcare service provider. Insurance companies may have a role if state owned or private owned healthcare institutions are not stepping in. Personally, I think that in Western Countries private companies are the ones most likely to set in motion the adoption of PDT in the healthcare space. A company that is providing healthcare insurance or healthcare services may start by requesting access to the EHR of that person and add to it specific information that is collected at the service subscription time. Furthermore, this first set of data mirroring the person's healthcare data is going to be extended as new data from exams, visits, prescriptions, monitoring devices are becoming available. This mirrored image of the person is used in the customisation of services and is made accessible, for the relevant parts, to

any medical doctor / healthcare provider that needs to interact with that person (duly authorised by the person that remains the owner of the data). By the end of this decade we can expect that the genome sequence will become part of the PDT.
Monitoring devices, wearables, implants... will continuously providing data that enrich the model and keep it in synch with the physical twin.
Applications embedded in the PDT leverage data creating a local intelligence. Additionally these apps (or other) interact with the environment through API (this is important to keep the PDT data separated from the environment, private, and to allow the interoperability of a PDT with its environment, including other PDTs, independently of the model / framework used in the PDT itself). Data values are shared on a need-to-know bases (hence a doctor can access certain sets and certain attributes, whilst a researcher may access a different subset and a healthcare institution a different one - as an example a researcher does not need to know my identity, a doctor does not need to know where I have been, only that I have been some places where a given risk exist, a public institution in general does not need my identity if the point is correlating proximity data...).
A crucial role of the PDT, as a bridge between its physical twin and the context is to create "context awareness", i.e. to inform its physical twin of threats and of the appropriate countermeasures (behaviour). It is also the PDT that has to inform here and now it physical twin of the regulatory framework (like "since you have been diagnosed as positive to Covid-19, you cannot go out) and in case the physical twin does not comply it should raise a red flag. Notice that this is not a violation of the privacy, nor a Big Brother incarnation. The PDT is actually preserving the privacy of its physical twin provided the latter conforms to the regulation. It is like the blackbox on a rented car that will not disclose my wandering / behaviour as long as I stay within the allowed framework, or speed trap that will not release information on cars unless they overspeed.
We have already seen (partial) implementation of PDT in China and other Far East Countries where during the pandemic each citizen had to have a digital passport to move around, a passport that was recording data, symptoms, test results.
PDT at stage V will be able to act proactively by analysing the context in cooperation with other PDTs and Digital Twins of healthcare services, resources shifting, as foreseen in this Megatrend, a significant portion of Healthcare processes to the cyberspace.

g) body-on-a-chip

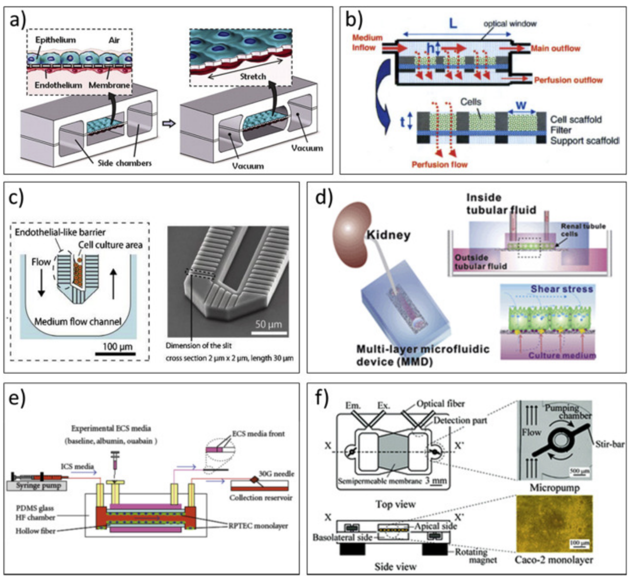


Fig. 77 Using electronic and micro-fluidic to replicate human organs functionality. [In this schematics]() replication of: a) lung, b/c) liver, d/e) kidney, f) gut. Image credit: Hiroshi Kimura et al, Elsevier

The development of micro-fluidic has made possible to duplicate the functionality of living beings by organising living cells on a chip and subjecting them to conditions that replicate the one of those cells in an organ. Once the functionality (and structure) is replicated it becomes possible to change the conditions (like varying nutrients, altering oxygen perfusion, introducing bacteria and drugs..). By observing the reaction of the cells, and the change in functionality, it becomes possible to simulate in vitro the behaviour of an organ under different conditions. The progress in this area has been towards the replication of a broader set of organs (we now have chips for [lung](), [liver](), [kidney](), [gut](), [skin](), [heart](), [pancreas]()) and to include more functionalities. For simulating some organs' functionality cells have to be organised in very specific structures, mimicking the one in the real organ and for this [bio 3D-printing is used]().
Lately, researchers have started to connect

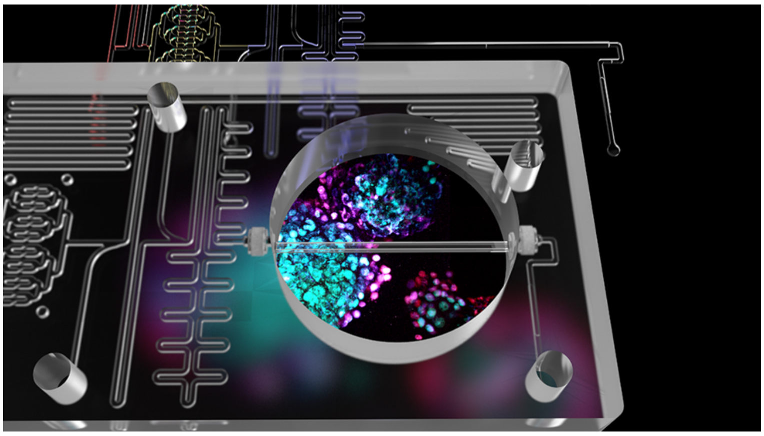


Fig. 78 The fully integrated, thermoplastic islet-on-a-chip (pancreas on a chip) was designed for scalable manufacturing, automated loading of islets into parallel channels, synchronised nutrient stimulation, and continuous insulin sensing. Image credit: Michael Rosnach/SEAS.

various organs on a chip to create more complex systems with the objective of creating a "body-on-a-chip" that can represent the complex interactions among the various body systems. Notice that this is not creating a "body", only a lab system to mimic specific functionality (besides a brain on a chip is still in the science fiction domain, although neurones are studied in vitro and have been integrated in bio-chips).

A first, obvious, use of this technology is for drug discovery/ testing. As a matter of fact the process leading to the commercialisation of a drug is a lengthy and costly one (a drug development may cost 2 billion $ taking into account all the dead alleys that have to be discarded). Microfluidic evolution along with data processing is expected to shorten the time to market and decrease significantly the number of dead alleys by the end of this decade.
A further expected evolution is the support to personalised cure, where a body-on-a-chip can be created using the patient cells to test a therapy in vitro. Here again, as previously mentioned, the availability of a personal digital twin may become important since part of the testing could be performed in the cyberspace.
Finally, by the end of this decade, early next one, technology of organ-on-a-chip can become so effective that (in some cases, like pancreas) the chip can be used to replace/flank the natural organ.

h) artificial intelligence

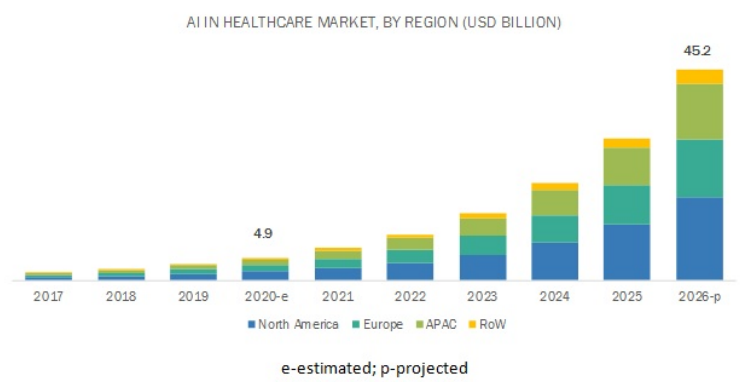


Fig. 79 Expected worldwide market for AI in the healthcare area. The shift towards tele-health, accelerated by the pandemic, is likely to further increase market demand for AI. Image credit: Markets and Markets

Artificial Intelligence is already used in medical field -applied AI-, particularly as support to diagnoses and prediction (data analytics). Predictive technology has become an important sector of AI in healthcare, looking at improving clinical decision making, managing and leveraging on EHR for risk assessment, monitoring data generated by wearable to raise red flags and augmenting medical devices. This latter will prove particularly important as we will be shifting in this decade towards more and more home care, preventative and personalised medicine.

Interestingly it is also starting to be used in detecting patterns pointing to processes resulting in better outcome (shorter hospitalisation, prompter recovery, fewer side effects/complications). The point is to use AI to find questions, not to find "answers"! The fact is that there are so many data, and data streams available in a hospital environment or in a medical practice that it is possible to apply data analytics to [derive questions](#) like "Why are there patterns leading certain patients experiencing better outcome than others?"

In this decade we can expect increased pervasiveness and use of AI in healthcare, as shown in the market forecast by Markets and Markets, figure 79, along the whole value chain:

- new drug design,
- assisted diagnoses, data rendering, automatic EHR updating,
- early diagnostic based on multiple data streams (ALS, cancer, dementia,...)
- assisted surgery,
- therapy identification and monitoring,
- assessing/predicting risks in specific population and at individual level,
- home healthcare, rehab,
- tele-care through virtual doctor,
- robotic/chatbot assisted healthcare, including natural language interaction, virtual nurses,
- doctor continuous education and medicine education for future doctors,
- identification of pathogen, of incipient epidemics, noxious substances,
- genotype to phenotype correlation, diseases related to genetic predisposition and ambient factors

By the end of this decade AI will be pervasive in the whole healthcare area, giving a fundamental contribution to personalisation, monitoring and cost reduction. It can be expected that AI will be embedded in services and medical devices, to be provided both at a centralised level and at a local level. In particular we can expect the embedding of AI in personal digital twins, to have this local intelligence growing over time and cooperating with centralised intelligence. PDTs are also expected to play the role of advisors, steering towards healthier behaviour the physical twin as well as raising the physical twin awareness on potential risks.

The growing pervasiveness of AI in this sector raises questions on privacy, accountability, transparency as well as on the digital divide that is created among the ones that will have access to this support and those that will not be able / allowed to access it.

Moreover, there are deep ethical questions in the use of AI. As mentioned cost is an important factor, often a driving deciding factor in the selection of cures. Cost aspects are necessarily part of the AI systems supporting healthcare. Who will be in charge of creating the ethical framework and of checking that it is being followed (this clearly connects to the transparency aspect)?

i) chatbots

Chatbots are seen as the ultimate interface between a person and the healthcare system assuring continuous access, anytime, anywhere, to healthcare consultancy.
There are already a number of [chatbots](#) on the market and more will become available. Some will be provided by independent third parties, other by insurance companies, other as a fringe benefit by the company you are working for and others by the official healthcare institutions.

Of all the innovations, novelty, in healthcare Chatbots are likely to become the signature of this decade in terms of their impact on people habits and way to deal with their own health. In a way it will have the same impact the cellular phone had on our way of looking at "communication". Before the "cellphone" we had to look for a "phone" and when on the move for a "telephone booth". It required a conscious search that created the awareness of becoming engaged in a "telecommunications". No more so. Today, telecommunications has lost the "tele" in terms of perception, we simply communicate when we want, wherever we are. Picking up the smartphone from the pocket, or the purse, is so natural that we no longer give it a second thought. Add to this the fact that we no longer have to dial a number, most of the time we just pronounce the name of the person we want to talk to, and you realise how seamless communication has become. A third, subtle but not less important aspect to create this seamless flow: we no longer perceive communication as a "cost". Most people today have some sort of all you can eat, with the consequence that a single call, or access to the internet, is perceived as costless (a telephone booth reminded us every single time that making a call had a cost!).

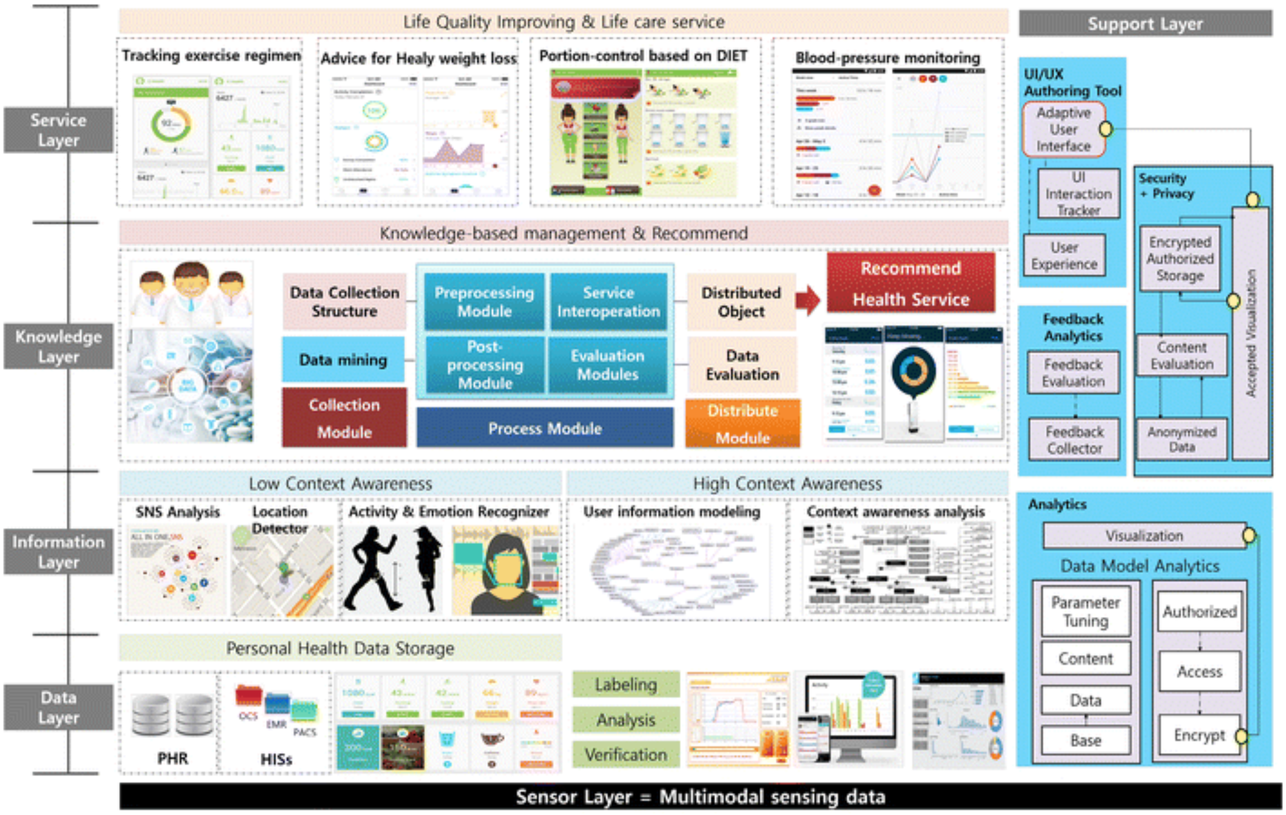


Fig. 80 Chatbots interface the whole value layers in healthcare from access to data to information and up to knowledge and services as shown in this graphic. Image credit: Kyungyong Chung, Research Gate - Cluster Computing

Now consider the chatbot in healthcare. At any time of the day, doesn't matter where you are, you can call *your* chatbot and talk to it (him/her?) telling that your throat feels sore. Ten minutes after that, looking at the menu of a restaurant, you call it again asking if a certain item on the menu would be ok, taking into consideration the pills you are taking... So here you see the same "continuity" of service that the smartphone is providing. You also see that you are not talking to a chatbot, rather to *your* chatbot, hence to something that knows you! (like pronouncing the name of a friend to call him only works if you are using your smartphone, because it is *your* smartphone. Thirdly, your chatbot will come as part of the healthcare service, you are not paying for its consultancy (at least that is the most likely situation in the future).

Today's chatbots have a limited set of "functionalities" and interact through natural language. In the coming years they will want to look at you and will be asking, sometimes -as needed- to use videoconference. Our face can tell quite a bit to a keen observer and it is most likely that the future chatbots will be using signal processing to check our heart beat, respiratory frequency, blood pressure and more (all of this just by looking at our face with the smartphone camera) and possibly will get further data collected by our smartphone (like our physical activity in the last days, hours and minutes) or by some wearables (smartwatch, fitness bands...).

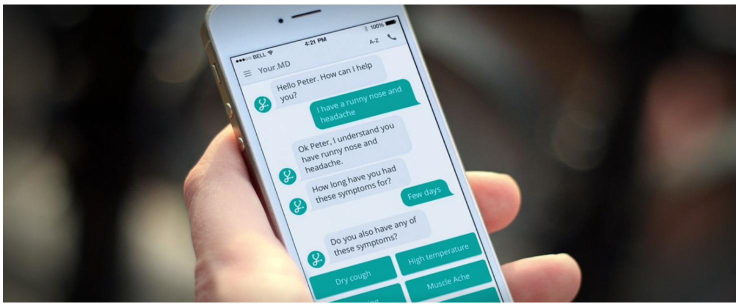


Fig. 81 An implementation of a chatbot (interface) on a smartphone. Using the smartphone as interface has the additional benefit of leveraging on a familiar platform/ User Interface. This is reflected by a recent poll showing that 96% of healthcare chatbot (patients) users find the interaction useful. Image credit: Proxet

Like your family doctor, actually better, your chatbot will know more and more about you as time goes by. The more you use it, the more it will be in synch with you. It will be the chatbot that, in case of need, will contact the appropriate doctor, sharing with her the relevant data and will set up an appointment or just provide feedback, depending on the situation.

This will be a profound change in the healthcare world, for us as users, and for all healthcare providers. Doctors will have to learn to interface with people's chatbots (and some biz models will need to be invented for these types of consultation) as well as to see their patient as a set consisting of a physical and a digital persona (the digital reality we are addressing in the DRI). Insurance companies will be competing on the bases of the kind of chatbot that can provide, and their efficiency will depend on the way the chatbot manages the consultancies with the client (person/patient). A pretty scary scenario arising from this business role of the chatbot in the insurance world is well described in the Robin Cook triller "Cell" (I would advise you to read it).

Not necessarily there will be just one chatbot for accessing healthcare services. Actually, I am pretty sure that doctors will start to offer their own chatbot to interface with their clients and they will be able to transfer part of their knowledge (and the specific knowledge related to that client) to the chatbot that will be interacting with him. Interestingly, the transfer of the chatbot acquired knowledge to the doctor will become an important issue, not just in terms of a notebook reporting symptoms, time of the call, prescriptions taken... rather in terms of general knowledge deriving from those interactions (a doctor learns every day by interacting with her patients, with the mediation of a chatbot she would be losing quite a bit!).

Chatbots and Personal Digital Twins will be intertwined, but I do not think they will be one and the same, mostly because of the need to keep separate ownership. The PDT will connect to the chatbot (possibly to several of them, since there will be others outside of the healthcare domain) but it will be owned by its physical twin whilst the chatbot may be owned by an insurance company (as an example). Also, we can expect our PDT to take the initiative to interact with the chatbot, in case it detects some anomaly in our physiology or behaviour and if needed have the chatbot calling us or prompting us to call the chatbot.

In addition to the above, all the evolution of genetic based diagnostic and cure (see the CRISPR Megatrend) will characterise healthcare in this and in the following decades. It is obvious that progress in genetic understanding will lead to more personalised diagnoses and cure. The challenges that we have today in correlating a given sindrome to a genetic map will be overcome through data analytics and artificial intelligence: the availability of hundred of millions, billions of sequenced genome create a vast pool of data that can support machine learning.

All in all, we can expect this Megatrend to lead to a new and better healthcare supporting the change in paradigm emphasising proactive and personalised support, aiming at keeping healthy rather than stepping in once people have become sick.

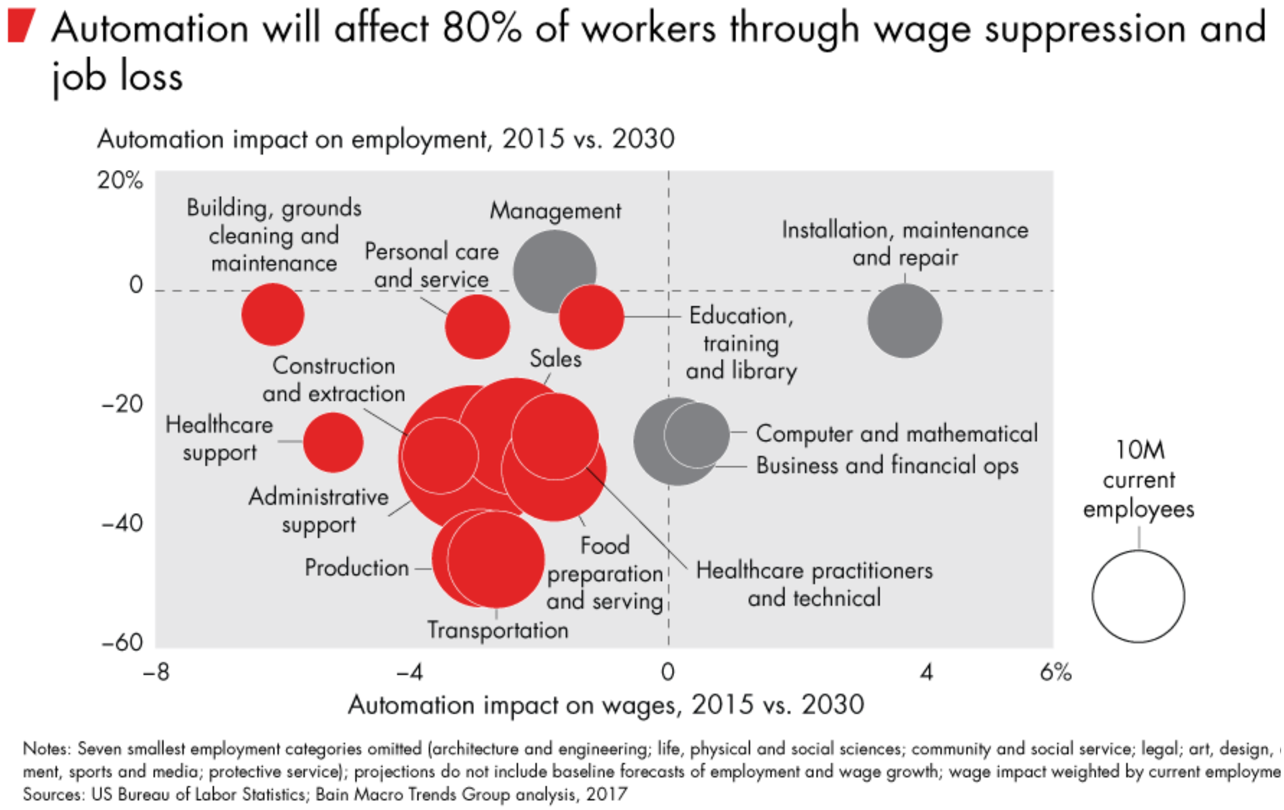


Fig. 82 A graphic representation of the expected impact in the US of automation in different sectors, measured as percentage of job losses/increase (vertical axis) and wage loss/increase (horizontal axis) taking as reference 2015 situation and 2030 forecast. The size of each bubbles relates to the number of people involved, red represents losses, grey gains in one dimension. Image credit: US Bureau of Labor Statistics

This Megatrend on the future of work is possibly the most complex one to analyse, and for this reason I left it at the end of this foresight exercise. "Work" is spread over so many areas that drawing a global view is basically impossible. There are also significant variations in different Countries and Regions but this is mostly affecting the timeline of evolution. In some areas transformation may already be ongoing and will complete within this decade, in others it has not started yet and may be far for completion by the end of the decade. However, it is mostly a matter of time (and local policies may have a significant impact). Eventually the transformation will affect all Countries, because they are all part of the same market and tick to the same economic rules.

When looking at the future of work we can do that from several points of view. A most important one is surely the one of "who" is doing "what" and in particular assessing the impact of automation (work delegated to machines). Figure 82 summarises the conclusion of a study by the US Bureau of Labor and Statistics discussed in an interesting report by Bain published in February 2018 "Labor 2030: the Collision of Demographics, Automation and Inequality". Although the data and forecast are US specific, the factors leading to the trends are applicable in a global context (sooner or later).

Even at first glance, it is clear that the impact of automation in the 15 sectors considered results in lower wages and loss of jobs (11 red bubbles signalling a loss, versus 4 grey bubbles showing a gain). Since the surface of each bubble is proportional to the number of people involved it is also evident that many more people are going to lose than to gain.

Gains are expected in Computer and Math related jobs, and in installation and repair jobs in terms of wages but these areas will see an overall job loss, whilst the Management area is expected to see increased number of jobs but at lower wages (no area seems to be gaining in number of jobs opportunity *and* in wage). We can expect a (slight) wage increase in computer and math related jobs because they require very skilled (and smart) people and this is a scarce resource. However, the number of jobs is expected to decrease as computers (and artificial intelligence) can take care of some activities. Same reasoning goes for Biz and Financial Operations. In the case of Installation, Maintenance and Repair we expect that although automation will be able to take care of some of the activities involved, most of them will still require actual human intervention and more and more skilled intervention, hence the expected increase of wages and the very limited decrease in jobs opportunities. As more activities increase in complexity and the processes shift from value chains to ecosystems direct human management is expected to grow but the abundance of related skill keeps wages decreasing.

In terms of job losses, it is expected that by the end of this decade some 20-25% jobs will be lost (1 out of 4-5 jobs will disappear) with low income workers being hit the hardest. The new wave of automation is based on two main pillars: Digital Transformation and Artificial Intelligence:

- the Digital Transformation moves a number of activities and processes to the cyberspace, with the consequent disappearance of jobs that were needed to run them in the physical space (think about travel agencies being hit by the on line end-user autonomous reservation and ticketing). Notice that DX is killing jobs not by substituting them with a machine but by removing them from the value chain (unlike automation on the assembly line where a robot steals the job of a blue collar, in the DX the job disappears). DX is going to hit most (in terms of jobs) the areas of healthcare and production (production already suffered from the first wave of automation with robots replacing blue collars, now it will suffer from the softwarization of production);
- the Artificial Intelligence augments machines capabilities hence making possible to replace human workers, including white collars, with machines. Administrative support jobs and sales are the ones suffering the most, as shown in the figure 82. Automation in the transportation sector, construction/extraction, food preparation and service, personal care and services will require a broad mix of technologies but artificial intelligence will be the crucial enabler.

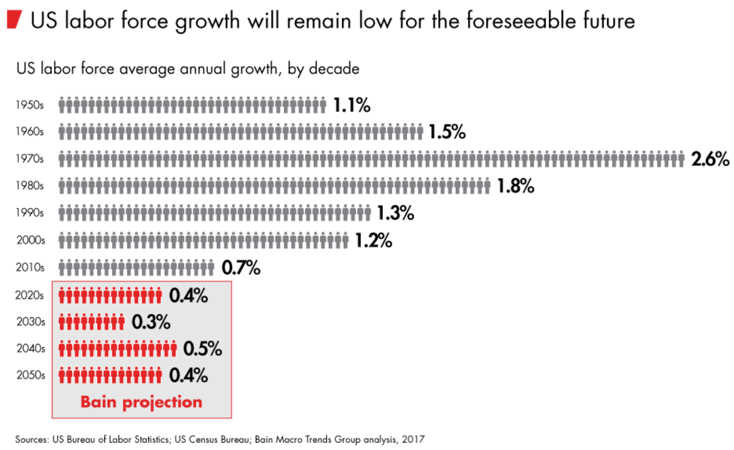


Fig. 83 Labor force growth in the last 6 decades and projection over the next 4. Image credit: Bain

It is important to notice that the drive towards increased automation (hence higher capital investment and job losses) is fuelled by the decreasing availability of work force, in particular of skilled work force. In turns this is bound to fuel inequality since the economic benefit of automation will go, mostly, to those having capitals (the rich) and those with crucial skills in high demand (estimated in 20% of the workforce). The two biggest economies, China and US, are already suffering from inequality and this

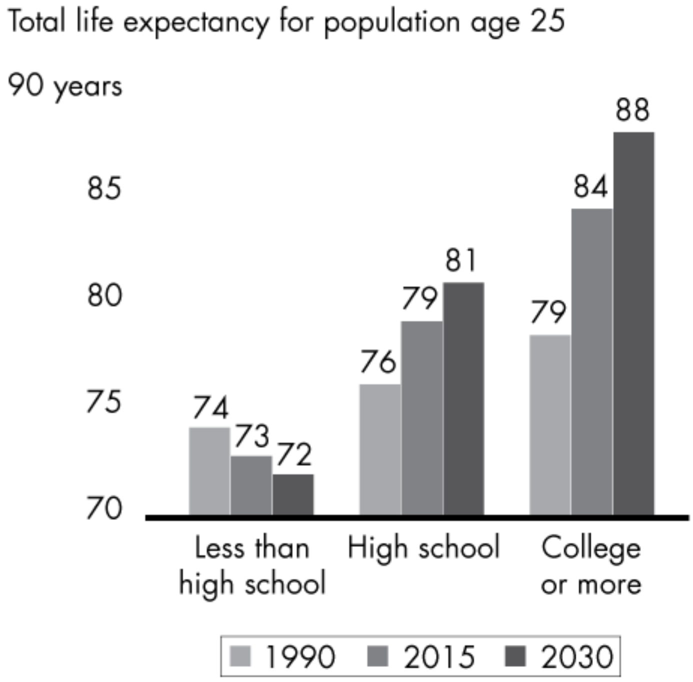


Fig. 84 Life expectancy is expected to increase in this decade with the exception of less educated people whose life expectancy will continue to decline.
Image credit: Bain

decade is likely to increase it. Also, the speed of automation uptake can have significant impact on inequality since a fast speed will create loss of jobs without providing the time for re-qualification (historical data show that workers re-absorption rate in the US was 0.7 million per year, in this decade the expectation is a job loss around 2.5 million per year, thus generating 1.8 million people that lose their job and cannot find a replacement) and would increase the demand for investment capitals thus increasing the leverage of rich people.

The access to resources, including healthy food, preventive healthcare and good cure is clearly influenced by wealth and the rising inequality will have a significant impact on life expectancy. According to Bain forecast, see figure 84, a significant impact is deriving from the education level, and this of course correlates to inequality and fosters inequality, to the point that the education level can be taken as the measuring stick for life expectancy in young people.

Rising inequality is also likely to increase Governments intervention thus changing, in several markets the balance between private and public. We are already starting to see this happening in Europe and other areas as result from the pandemic stress on the economy.

GDP growth in the last 65 years (1950-2015, see figure 85) was fuelled in equal parts by workforce increase and productivity increase. In this decade the workforce (the one needed, with high skill level) is bound to decrease in several areas (like in Europe by 0.5% per year) or not be au-pair with the growth in the previous decades (in the US the expected growth for this decade is 0.4%, less than half the ones of the previous decades). To keep the GDP trend, productivity has to increase and automation is expected to result in a 30% productivity increase by the end of this decade.

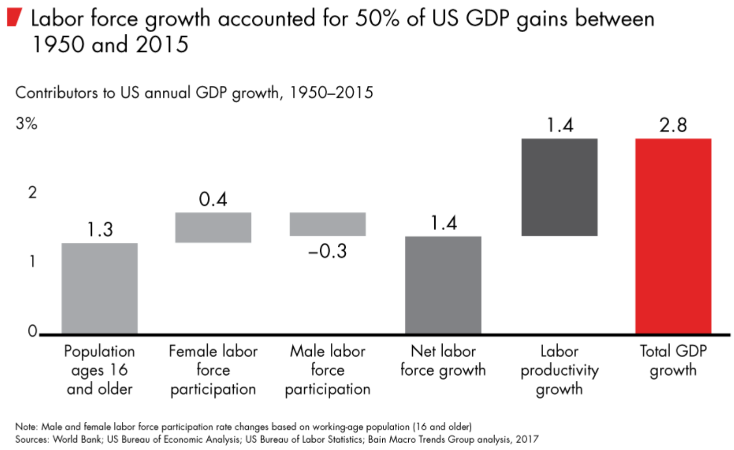


Fig. 85 Over the period 1950 to 2015 GDP growth has been generated in equal part by the increase of productivity and increase in the workforce. As workforce increase slows more investment is required to increase productivity to keep the rate of GDP growth.
Image credit: World Bank

a) The future of work is now, or isn't it?

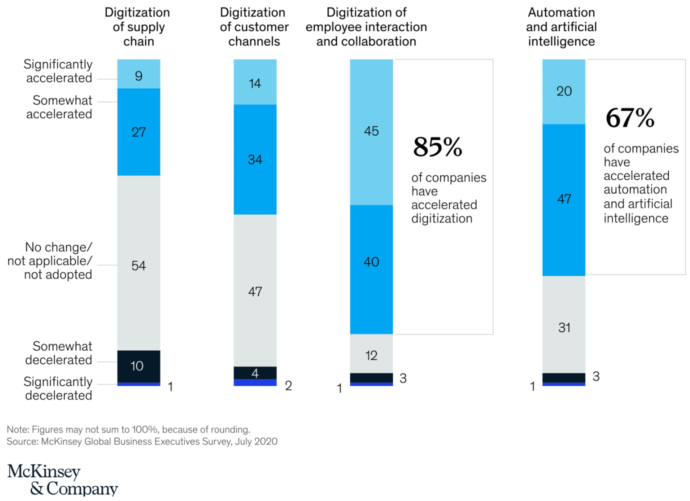


Fig. 86 Measures of digitization and automation taken to counteract the impact of the pandemic. It is clear the acceleration of towards a digital transformation (blue shades) of the various processes. Image credit: McKinsey&Company

In the past year we have seen, and possibly contributed to, a momentous shift in the way of doing business, courtesy of the pandemic and of related countermeasures taken by governments all over the world. Not even the world wars of the last century have led to such dramatic change, in such a short time involving so many countries.

One of the most amazing thing was the resilience of business that in the space of a few days managed to find ways to ensure operation continuity.

Clearly not every biz was able to reinvent its operation processes or to keep them operational by moving to the cyberspace. Think about the tourism area where movement restriction imposed by authorities led to a screeching halt of this business, affecting airlines, airports, catering, tourist attraction, hotels ...

Other businesses, like healthcare and telecommunications, had to face a surge of demand and others had to move (part of) their operation to the cyberspace like retail, banking, ... sometimes inventing new channels to reach their market.

All of this is well represented in the previously mentioned study by McKinsey involving some 800 executives on the post pandemic lingering effect on business and on workforce, see figure 86. As shown, close to 50% indicated changes in the supply chain (36% foresee an increased digitalization and 11% a decreased one) and similarly a change in the customer channels (although here the foreseen changes were overwhelming in the direction of increased digitalization). More interesting, with respect to this trend, are the expected changes in operation (employees interaction/ collaboration and automation/artificial intelligence).

85% of interviewed companies indicate an acceleration towards digitalization in the area of employees interaction and collaboration (remote working and all what is connected) and 67% foresee an increase of automation and use of artificial intelligence.

Teleworking has been adopted wherever it was feasible, like for administrative work, education, software production and testing, plants control ... involving a significant portion of the workforce. In Italy, as an example, TIM, one of the major telecom Operators, had 85% its workforce working from home for almost a year now (since the lockdown started in March 2020). The experience was a mixed bag, in terms of productivity, employees and customer satisfaction. On the whole, customer perception of the services did not change (remote customer assistance and interaction was already a reality before the pandemic), productivity did not show significant changes (at least in the short term) whilst employees satisfaction ranged from appreciation of the convenience of working from home to the concern of losing the human touch that is possible at the office in face to face interaction with colleagues. Quite a few found that the convenience of tele-working was (at least partially) offset by the cramped working conditions at home (with an office that had to be shared with kids, pets and spouse) to the point that many tele-workers are longing for the old office space and hope to go back to the old times. This, for many companies, is unlikely to happen. In the cited example of TIM, the company has taken advantage of the forced lockdown and tele-working to change the office space into shared desk. Workers were asked to remove all personal stuff from their desks since the concept of personal desk was over. From now on, when on site working will be resumed, only a fraction of the workforce will operate on site, about 30 to 50%, the remaining part will keep working outside the office. The office space will become available on a first come first served bases through reservation. This has led to the release of office space and decrease of premises cost.

If on the one hand it is obvious that the pandemic has changed the way of working for a significant portion of the global workforce, the question now is if these changes are here to stay (as in the afore mentioned example of TIM) or if there will be a roll back to the previous "normal", secondly if they are here to stay what kind of consolidation will take place and therefore how the work by the end of this decade will look like and third what other changes may occur as result of the changes induced (or accelerated) by the pandemic.

Let's consider the first question: are the changes brought by the pandemic going to become the new normal?

I guess that a single answer fitting all businesses and countries does not exist; however, in general, I would say that NO, the changes brought by the pandemic are not the new "normal". Let's consider a few examples:

- In some cases we are going to see a full roll back to the previous situation, like in the case of restaurants that have been forced to move to "take away service" and want to go back to serving customers on their premises. A small number of these restaurants might be keeping the take away service as an additional revenue stream, since they had to organise the service to generate (some) revenue during the lock down. The extent to which this may happen will largely depend from the demand side. Will customers (at least a significant portion of them) be interested in the take away service from restaurants that used to be on premise service only (usually upper scale restaurants)? I personally think that at least in the first post-pandemic period most people will want to forget the pandemic experience and go back to the previous habits, so no take away but enjoy an evening out. The behaviour of the demand is, obviously, very much culture based and Countries where people are used to take away may see the expanded offer well fitting their whims, whilst other Countries, like Italy, may just want to forget the past and go out again.
In those places where the take away food is going to flank the on site service it is likely that some stable reorganisation of work will take place to be able to manage the two types of services. In fact, delivering take away food, particularly for upper scale restaurant, requires a fine tuning of the menu (not all dishes are suitable for take away given the time lag between the kitchen and the table) as well as the ordering and delivering processes. During the lock down restaurants did not have customers on site so they could focus on the take away. With

Fig. 87 Flippy, a kitchen robot for fast food restaurant can prepare burghers and salads. Demand is expected to grow as restaurants face Covid-19 restrictions. Image credit: Miso Robotics, California

on site customers two different processes will have to be managed concurrently. Automation can surely help, although so far restaurant automation has served mostly lower scale restaurants but in the future better robots might be able to enter upper scale restaurants too and directly take orders and coordinate with the delivery chain. I do not see this happening, on a massive scale, through this decade although a few trials may start.

- Retail stores have their strength in their location and in the physical interaction with customers. Many retailers have invented a new way of interacting with clients using sort of videoconferencing where a prospective client would call and the shop assistant would move around the shop showing the wares using the smartphone cameras. That has been a patch to a dire situation and clearly those retailers are just pressuring to go back to the old normal. In a way managing the client relationship via a smartphone camera was an expensive way of doing business (it takes the continuous presence of a shop assistant to be with the client...) and still the physical experience could not be delivered. At the same time good shop assistants had the opportunity of a continuous engagement with the client, they could steer the client towards certain products and in doing so they developed a personal relationship that could be conducive to a better revenue stream. They also got the identity of the customer (their telephone number) and this could have been the starting point for a profiling and for a call back when a certain product becomes available. As in any crises, some retailers just patched up a dire situation, others might have found an alternative way of doing business that can complement the old one, once the old one can be restored. Overall I think retail stores will go back to the old normal, but the few ones that have learned to create a personal, although remote relationship with customers will be in a position to create a new, complementary revenue stream that eventually may become essential as the competitive pressure from on-line retailers keeps growing. Actually, the pandemic has increased this pressure creating a habit in the consumers to use on-line retailers.
Notice, additionally, how this form of retail, let's call it click and mortar, requires quite different skills on the side of the shop assistant, because of the need to establish a lasting

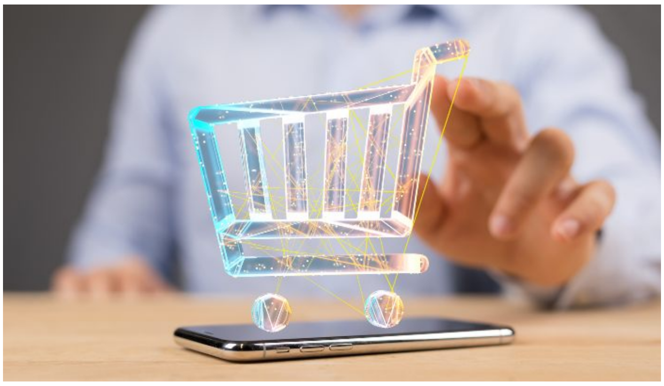


Fig. 88 The integration of physical and digital shopping is most likely the future of shopping and there's a new word for this: Phygital. Image credit: WAM

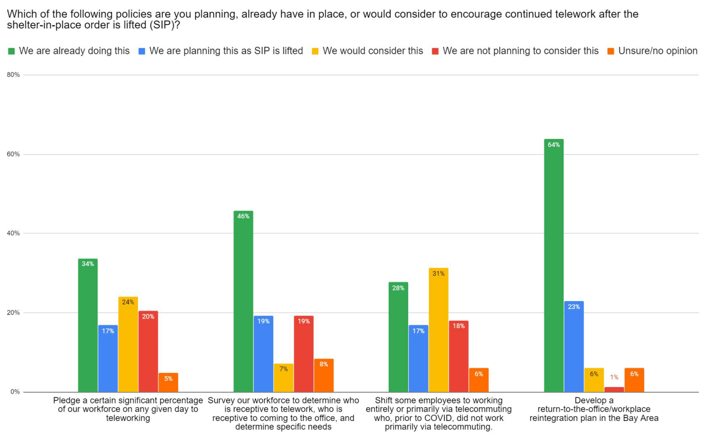


Fig. 89 Results of the polling of 83 CEOs of innovation companies in Silicon Valley on their plans towards teleworking in a post Covid landscape. 51% are planning to keep teleworking for a significant percentage of their workforce, over 60% will survey their workforce to see who is willing to telework, 45% will impose teleworking to a part of their workforce and 89% will develop a plan for returning to work on premises in a different way. Image credit: The Silicon Valley Leadership Group

relationship with the client on one side and to highlight the value of a product using a virtual channel. Technology has to become an integral part of the assistant interaction, sometimes having to cover shortcomings in technology management from the client side.
There is even a new word to put under the same roof the on-line with virtual reality / haptic interfaces (to make you feel in the shop physical space) and the in-the shop experience flanked by the on-line presence: phygital. Take a look at this (entertaining) video and to this look into the future today video.

- Companies that are working in the "cyberspace", like software companies, are clearly in a different position from restaurants or retail stores for which the physical space is a must. This shows in the relative easiness of their shift to teleworking and most important in the lesser way they have been affected by the pandemic. The production part of their business has been mostly unaffected by the lockdown. The sales part, on the other hand, has suffered both directly (loss of personal contact with prospective clients have made selling propositions more difficult) and indirectly (a significant portion of their potential customers base have been affected economically by the pandemic leading to decrease investment in innovation. In some cases, a smaller percentage, they have experienced an increased demand from companies that needed their product/services to shift their biz to the cyberspace).
Part of these companies were already operating with a remote workforce, either teleworking from home or located in different places/Countries. What the Covid-19 did was to increase the number of workers operating from remote (home) to the point that several companies premises have been closed. From a productivity point of view, in the short term there have been no losses, actually a number of companies are reporting increased productivity level (commuting time is often converted, at least partially, into productive time). Some chit-chat typical of office work has disappeared increasing productivity. However, this is a mixed bag since although part of that chit-chat is inconsequential, a part may result in knowledge spread, creative thinking and serendipitous discovery. Furthermore the chit-chat is perceived by several workers as a bonding that is sorely missed when working from home.
This latter brings up the point of how workers are adapting to telework and their willingness to keep it once the pandemic will be over. Commuting time is perceived as wasted time by most, and as a cost by all. Hence working from home is better in that respect. However, in addition to the loss of the human touch deriving from on-premises interaction, there are a number of negative perception playing against teleworking:

- home ambient may not be ideal for work
  (kids, pets, spouse, dedicated work space not available/unsuitable);
- presence of distraction and lack of focus (difficult to separate home chores from work)
- fear that one's work contribution is not perceivable by the "boss"
- fear of becoming monitored by the "big brother"
- fear of losing the "big picture"
  (a side effect of living and sharing the company physical space)
- losing the sense of being part of a team, small talks and physical co-presence are crucial
- inadequate collaborative tools
  (video conferencing is ok for a short meeting, becomes unnerving if using for a whole day)
- video fatigue

It is also about how managers feel about teleworking. The loss of direct, physical co-presence is felt by several managers as loss of control. Notice that control taking place at the office as a passing glance is not perceived as inquisitive whilst a control taking place in the cyberspace is felt as a loss of privacy and strongly adversed.
It goes beyond the loss of control. It is also about loss of serendipity, about the casual opportunity of pointing out something in the middle of a small talk, of motivating people

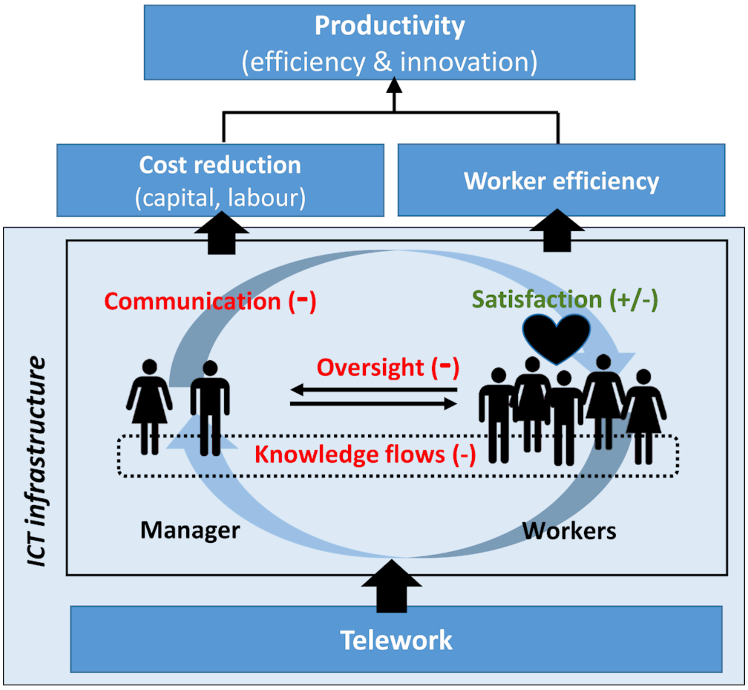


Fig. 90 [Pros and cons of telework](), as seen from workers and managers. Workers satisfaction is a mixed bag, with a prevalence of positive aspects. The communication, knowledge exchange and oversight effectiveness are all suffering from teleworking. Image credit: OECD

with subtle signs, like a handshake or a smile.

All of this is true in the short term. But what about the longer term?

Will productivity remain constant or will start decreasing? Will people get used to telework so that the negative perception of some factors will fade away? There are, obviously, statistics on teleworking since millions of people have been teleworking for years now, however this is about those people, and those jobs, that used to work on premises. One of the structural issues about this pandemic forced teleworking is that it has not been designed from scratch, it has been imposed by external necessities. Hence, working processes used were/are the ones deemed effective to work on premises; these processes may not be an ideal fit when applied to teleworking. As a matter of fact, this was a recurring theme when I spoke a few months ago with a number of CEOs to discuss the new working landscape deriving from Covid-19 countermeasures: there is a need to re-think processes. This is not a minor issue, particularly for big companies that operates on an infrastructure made of processes. This is also a reason why a number of companies are finding a process re-engineering costly and will go back to the "old" normal as soon as possible.

- Between those business that are rooted in the physical space (like retail stores, restaurants, transport, hotels...) and those that are already living in the cyberspace (just addressed in the previous post) there are plenty of other businesses (like the whole sector of manufacturing) that are rooted in the physical space (the factory) but at the same time have a significant portion of the workforce that can operate in the cyberspace (administrative processes, customer relations, monitoring processes, ...).

In most of these businesses the workforce operating on those processes has been using computer assisted tools and, in fact we have seen that the pandemic response was to have this workforce shifting to remote working. This is what the WEF calls: Everyone who can must work from home.

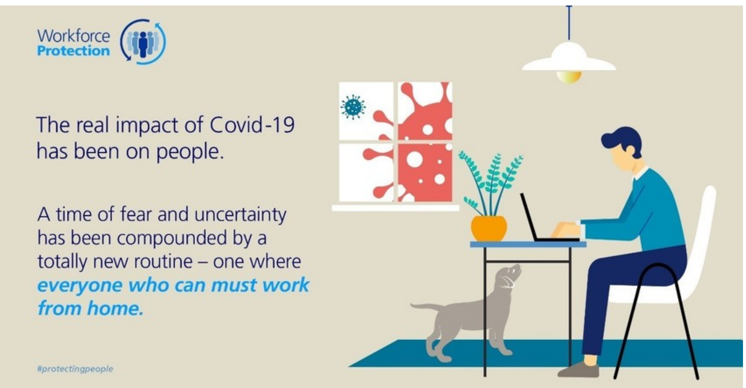


Fig. 91 Everyone who can must work from home. This has been the Covid-19 main message to workforce with effects that will be lingering throughout this decade. Image credit: WEF - Zurich

However, many companies undertook this shift with plenty of reservations, with security consideration being an important factor. The physical presence of workers on company's premises provided a protected environment for work in line with security procedures. Processes have been finely tuned over time to fit that particular working environment. Changing the company's premises for private homes that are no longer controllable created quite a bit of anxiety for CEOs and security heads. On the workers side, working from home took away the technical support that they were used to on the company premises. Unlike technical (software) workforce, administrative workforce has very little familiarity with the inner working of the tools they are using. Any problem is referred to a support team that was, clearly, no longer available at home.
This has brought to the fore the problem of re-skilling the workforce and indeed several companies have engaged in a retraining program to ensure a minimum of skill supporting remote work. Even something as basic as video conference had to be learnt.
Additionally, considering teleworking from home as a stable situations (which turned out to be the case as the pandemic stretched countermeasures over several months) companies had to recreate a sort of company's premises "decentralised cocoons" at the homes of their workforce:
- fast, secure and stable Internet connection. The link capacity -fast- was not really dependent on the company, it had to match with current network availability. However, in several cases there might exist several options to ensure a good connectivity, like using a wireless link. A number of companies provided wireless connectivity access via dedicated company smartphone tethering;
- set up of private virtual network to provide secure access to company servers (applications and data);
- assign the required devices to workers, like laptops, smartphone ...
- train workers on security aspects

Fig. 92 Real estate in the cyberspace is a growing business. A company may use a cyberspace "location" to create their offce space with all support that would be available in a physical location (the one that still makes sense, no heating/air-conditioning needed ... Image credit: eXpRealty

Beyond providing this basic infrastructural set, companies had to revise processes and identify the proper digital channels to be used for each of them (as an example when to use a chat, a common communication area, a videoconference) and how to manage document flow (sharing documents for concurrent perusing and updating vs creating a sequence of steps defining ownership for each one), creating mailing list, authorisation check points...
Work on company premises is regulated by a context, like: everybody shows up at 9am every week day. Working from home provides much more flexibility letting people to work, potentially, at odd hours. Sometimes this may not be in synch with a team work so that rules have to be enforced.
To make up for the physical separation alternative ways to create a team "spirit" have to be found, setting up specific moments for socialisation, although mediated by digital channels and one-on-one interactions with the supervisors. The increased flexibility in work organisation shall be complemented by very clear objectives, KPI and milestones. This may

be easier for certain types of activities than others.

All of the above are useful guidelines, however, in the long term, companies need to realise that a massively distributed workforce, operating from remote, requires a significantly different work organisation, a different set of tools and this leads to a new working and workforce landscape.

In this decade we are going to see an increasing use of virtual office space in the cyberspace. This has the root in the ideas proposed and tested by [SecondLife]() at the turn of the century (SecondLife was launched in 2003) that for a few years generated a strong interest also from the business sector. One of the problem with SecondLife was the perception of a "fake" world that eventually discouraged people and business, after the first wave of enthusiasm. Now, however, we have better technologies available (better and widespread connectivity mostly) and a growing shift from application to data (rather than having applications to generate and manipulate data we have data that stimulates the creation of applications). The pandemic, as previously noted, has forced the shift to the cyberspace for many industries - wherever possible. In this framework the development of offices in the cyberspace becomes a need.

An example may be eXpRealty, a real estate company, having several hundred people and providing them with offices, meeting rooms, auditorium and more all in the cyberspace (take a look at this clip).

I am sure there will be huge biz opportunities for companies that will provide a full package of services for companies to set up offices in the cyberspace and that will likely become a very profitable market by the end of this decade.

b) forces reshaping work in this decade

Fig. 93 The changing relevance of knowledge and the ways knowledge keeps its value and can be accessed is a factor in the shaping of the future of work in this decade. This graphic shows the decreasing half-life of knowledge, from an average of 30 years in the last century to an average of 6 years today. Furthermore the knowledge learnt today at school is not the one that may be needed on the workplace. As shown in the graphic, 65% of children entering the primary school will end up in works that are not existing today and whose need of knowledge is difficult to predict.
Image credit: CNBC - Future of Work Report

The acceleration of the Digital Transformation resulting from the pandemic and the changing way of working cannot be used as a measuring stick for what may happen to work and workforce in this decade. In the short term it is obvious that pandemic had/has a huge impact, however over a longer period of time the changes will depend on other forces. Quite a few companies are just waiting for the end of the pandemic to rewind the clock and go back to biz as usual. The point that pandemic has taught us a lesson and therefore companies will change their way of doing business to be prepared for a possible new pandemic is not, I think, the way biz works, nor as humans behave, unfortunately. We are quite sure that an eruption of the Vesuvius volcano will happen, yet people are still building houses on its slopes... Likewise for pandemics; we know from historical data that a new pandemic happens every 100 years on the average (the present one hit right on time!) but a hundred years for a business is a long period of time. If changing the way of working is done for achieving an advantage that can be reaped in a hundred years time, but may have some disadvantages in the short term, that will just not happen (unless some kind of regulation is being enforced, but this is also unlike, since the regulators take into account the biz landscape. If a regulation will put companies at competitive disadvantage they will think twice before enforcing it).

Hence, in discussing this decade Megatrend on the future of work we should consider the driving forces reshaping the work landscape, considering the pandemic impact as an accelerator of change where changes are in line with those driving forces and disregarding other changes that most likely will be rolled back once the epidemic is over.

To me these driving forces are:

- distributed knowledge - Human Cloud
- Gig Economy
- artificial intelligence driving automation
- Distributed knowledge shared by humans and machines

It is obvious that to take effect these forces need to leverage on technology (features, availability and affordability) and it is also true the opposite, that tech evolution strengthen these forces. Hence a reinforcing cycle that has already started to take shape.

I already addressed the economic, demographic and environmental (ecological awareness) factors that are shaping, fostering and constraining the evolution of work in this decade in the first part of the discussion of this Megatrend, Now I am going to focus on these tech-related forces.

c) Distributed Knowledge - Human Cloud

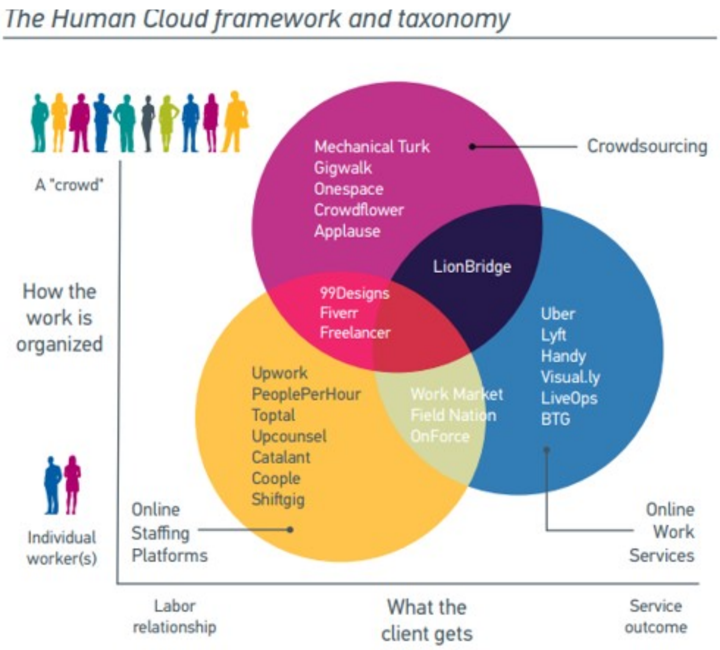


Fig. 94 A nice graphic placing in relation the organisation of work, from being based on individuals to being based on a "crowd", with the client relation, from interacting with the labour provider to interacting with a service. Each bubble list a number of companies in that space. Image credit: Staffing Industry Analysts

It is quite obvious that knowledge is disseminated more and more and we have now plenty of tools to foster the growth of this disseminated knowledge, starting from its sharing to step by step improvements (internet and the web made this possible in an efficient way) as well as to make sense out of this distributed knowledge (we are just starting in this area).

Clearly the "location" of knowledge matters, since it relates to accessibility, credibility, ownership ... and quite some effort is focussing not on access and sharing, rather on protection and encapsulation.

It is nothing new, actually. Human beings as knowledge repositories have been the platform of distributed knowledge for millennia. What has changed more recently is that this human distributed knowledge, also addressed more recently with respect to the leveraging of such knowledge as "the human cloud", has become more and more accessible as a whole, as communication among humans has increased its effectiveness (you can connect two "minds" in a matter of seconds, independently from where their "brain container" is located). The adoption of a standard language, like English, has further improved the communication.

The Human Cloud is seen both as the ensemble on distributed knowledge (and skills that sometimes are more important for industry) provided by humans and as the infrastructure connecting this distributed human knowledge and ensuring access to it. The yearly investment on this infrastructure has reached 80B$ and it is expected to keep growing in the coming years.

Part of the "story" when looking at the human cloud is about mobility of humans (both physical and virtual). Companies have been used to consider work on (their) premises and to tailor salary ranges to the cost of life in that area. This approach does not work when considering the human cloud. People keep moving around and it does not make sense to correlate salary to a specific location. Notice that a few companies, as are allowing remote working in this pandemic time are also imposing wage cuts on the assumption that if you no longer need to live in San Francisco you can live with a lower salary.

The existence of an accessible Human Cloud will increase competition among workers (at least certain types of workers, particularly in the technical sectors and for all activities that can be delivered "spot") but will also make competition for access to these resources much more intense and the need for an effective human cloud infrastructure support crucial. Also challenging is the assessment of knowledge (and skill) to get the one that fits best the need at hand. You don't want to overshoot, and also you may not be able to rely on previous choices since knowledge obsolescence is just accelerating as shown in Figure 93.

It is reasonable to expect that the Distributed Knowledge and the creation of effective Human Clouds are going to reshape work processes and the workforce, fuelling an extended Gig Economy.

d) Gig Economy

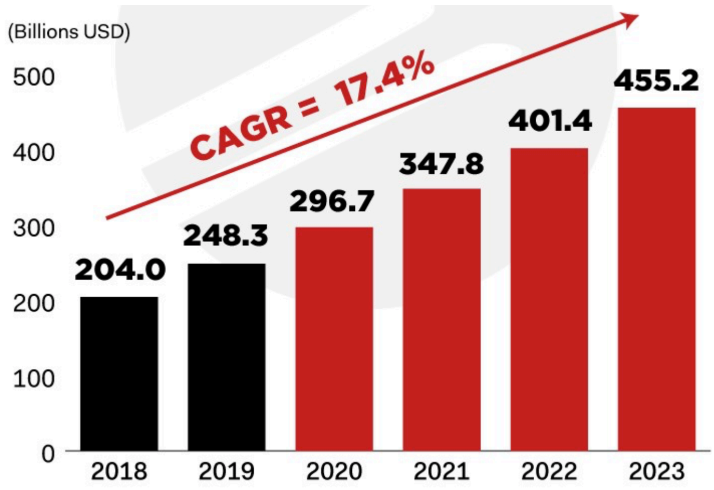


Fig. 95 Gig Economy us expected to grow by 17.4% CAGR over the next 3 years to reach 455 B$ in the US. Image credit: Nasscom Insight, data from Statista 2021

The Gig Economy started as little (gig) works requiring very limited skills, like delivering food in the neighbourhood requiring very little resources (a bike would do) or fixing a rusty bannister ... The person offering the services was doing that on his own schedule, would do that today but not tomorrow. No obligations beyond that specific task/ time limited commitment.

Compare this with the (mutual) contractual obligations between an employer and an employee and you immediately perceive the difference. The contractual obligation ensures the employer to be able to deliver a service as needed by making sure of the availability of the needed resources (the employees) and provides the employee with a continuous wage.

Technology can bridge these two approaches creating platforms that decrease the cost for offer to meet demand and provide access to a pool of resources that, statistically, would ensure continuity of service: all people with the skill of fixing a rusting bannister can declare their availability at any given time and all people needing someone to fix that rusty bannister can get in touch with someone willing to take up that job. These platforms are the engines of the Gig Economy and each one is, usually, a company of its own.

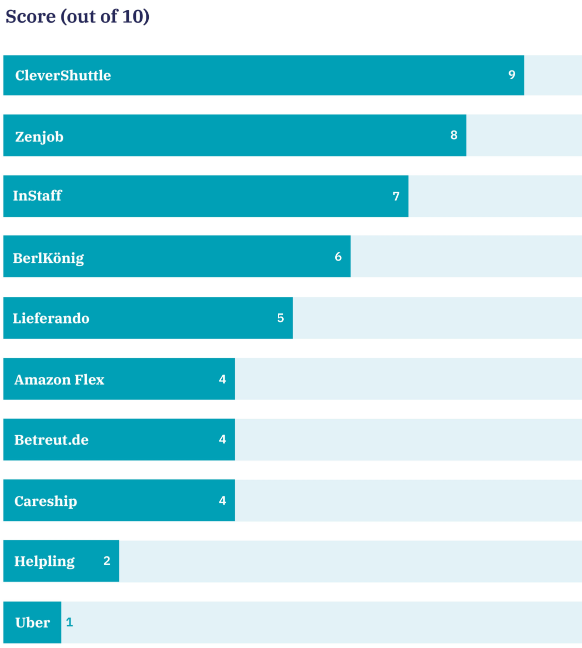


Fig. 96 A list of gig economy platforms/ companies operating in Germany ranked according to a list of fairness principles (pay, conditions, obligations, management, representation). Image credit: Fairwork Foundation

Platforms decrease transaction cost, they make the whole process of delivering a service more efficient. This is not as good as it might seem at a first glance! A company creating a platform slash the cost of doing business, hence many more people will be able to offer their service using the platform: offer increases and, as in any competitive system, the price of the service is going to decrease, favouring the end customer. At the same time the alternative for someone wanting to offer their services outside of the platform is basically not existent, because of the efficiency provided by the platform (i.e. it will cost much more for the offer to meet demand). This creates an asymmetrical situation between the company owning/operating the platform and the people using it to offer their services. The company holds all the cards and can end up exploiting the ones that are actually delivering the service. We have seen the protest of riders claiming (with good reasons in general) to be exploited, underpaid, forced to work even if they are sick,... This is the result of the asymmetry and of the efficiency provided by the platform that in presence of an offer that exceeds demand leads to a compression of values (wages). The issue has become a sensitive one and organisations like Fairwork have identified a set of principles to evaluate these platforms (companies) using parameters like:

- fair pay: decent pay, based on the service provided, that should be paid on time and cover all work completed;
- fair condition: appropriate work conditions should be enforced, decreasing occupational risks (the high competition often enforced by platforms push workers to cut corners and take risks);
- fair contracts: although there may not be a specific labour contract, the access to the platform and the way the work process is managed (distribution of demand, monitoring of activity, ...) should be transparent;
- fair management: decisions affecting workers (like way of ranking and assessing quality) should be transparent;
- fair representation: although the relationship is between a gig worker and a platform, workers should have the right to self-organise and to appeal to decisions taken by the "platform/company".

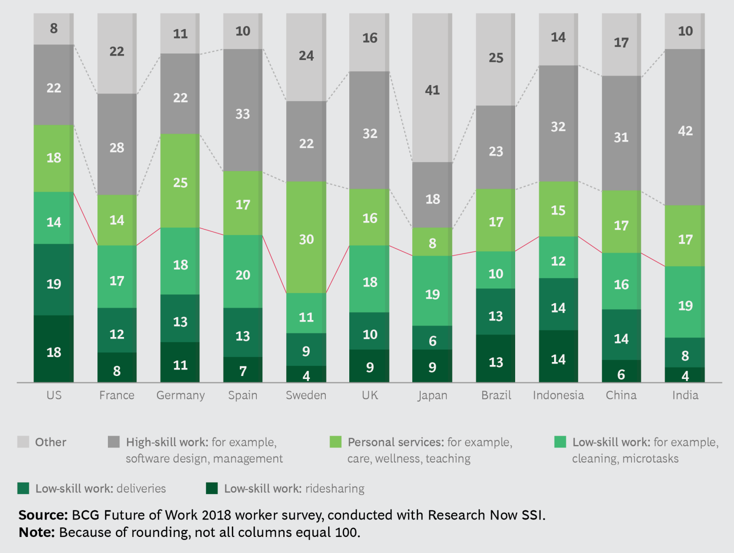


Fig. 97 Growth of freelance work. The Gig Economy is expanding towards higher skill markets and more and more workers are looking into this as a different way of micro-entrepreneurship, providing flexibility and independence. Image credit: BCG Henderson Institute

Working conditions have indeed worsened in several cases, as should be expected when the offer is high and the competition drives for more and more efficiency at the expense of the "offer", i.e. the gig workers. It is the result of the basic economic rule that in every competitive systems the price of a product/service tends to the marginal cost and in this case the marginal cost is approaching zero (it costs nothing, but time and fatigue, to ride a bike to deliver a pizza). This is why some sort of regulation is sorely needed.

The problem is not felt in those situations where demand is high and offer is low. In this cases the gig workers are the ones having the upper hand, like in consultancy areas. Consider how much a company has to pay for a consultant service provided by a consulting firm. Quite a lot and the more skilled the consultant required (there are very few of them) the more the consulting firm is charging. By leveraging on a platform, a consultant can access the demand directly and because the bridge takes place in the cyberspace a consultant will experience an increased demand, hence can charge more! This is not the case in delivering pizza, since this service is constrained by the location (a gig worker in LA cannot benefit from a demand in San Diego…) thus having a limited demand, and potentially a big number of “riders”.

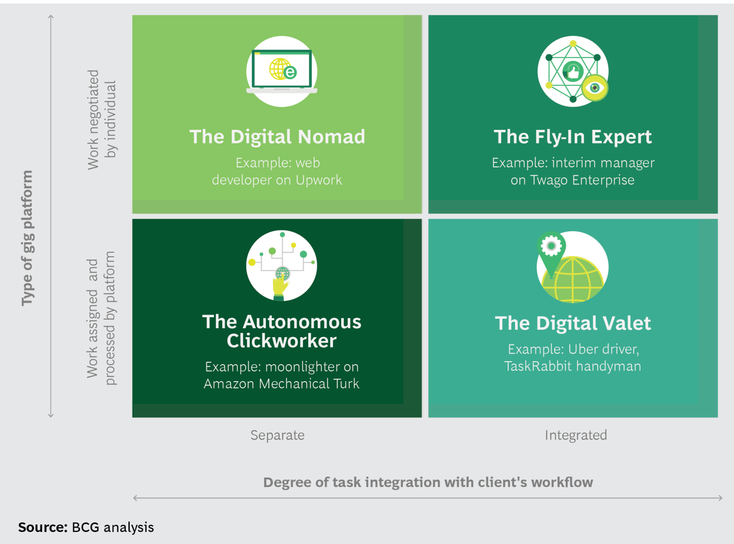


Fig. 98 The four different types of freelance work, identified by the type of platform (platform assigns job versus job negotiated by the individual)and by the relation with the client (separated vs integrated). Image credit: BCG Henderson Institute

Notice that because of the efficiency introduced by the platform, both the consultant and the company using the consultancy are winning: a consultant that would make 200,000$ a year as an employee of a consulting firm gets payed, roughly 100$ per hour. As freelance consultant he can make at least 3 times as much, per hour. If you look at this from the company seeking the consulting service, it means that their cost is slashed. Rather than paying the consulting firm some 1,500$ for a spot-consulting they will pay the consultant 300$, one fifth (these numbers are based on my real experience, in providing consultancy as freelance over a number of platforms. Figures change quite a bit depending on the type of consultancy but the concept is clear). So both the freelance consultant and the company using the service are gaining. Who is losing? The old style consulting companies that are seeing their way of

doing business superseded by the shift to the Gig Economy. Indeed, most consulting companies have started to offer consultancy platform-based, as a new business proposition, keeping the "old" way for those consultancies that involve a long term effort.
There is now, and so it will be in this decade, a broad spectrum of working types in the gig economy as shown in figure 98.

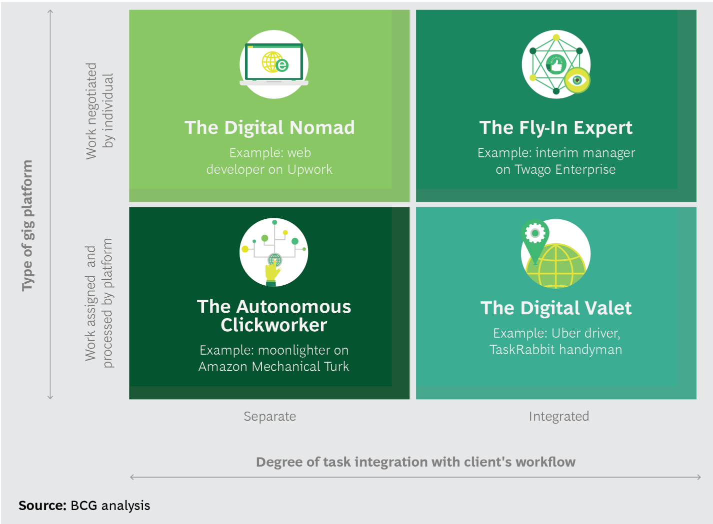


Fig. 99 The four different types of freelance work, identified by the type of platform (platform assigns job versus job negotiated by the individual)and by the relation with the client (separated vs integrated). Image credit: BCG Henderson Institute

There are/will be platforms that manage demand and, based on a policy and resources availability, connect demand to offer, i.e. send the demand to one of the available resources (a freelance worker). The worker has no visibility on the demand landscape, just respond to a request. This is the case of the Amazon Mechanical Turk, a platform that manages, in principle, any type of offer connecting it to any type of demand (a work marketplace). It really looks like the Amazon marketplace where companies offering their product have no control over the demand. They are just told that someone is asking for their product and they will deliver. A similar situation is the one of the Uber platform where the offer of the service (transportation) is allocated by the platform to a specific demand (based on platform's criteria, including the shortest time to pick up as well as the rating of the drivers in the area). In this second case, like in the previous one, the connection between offer and demand is still decided by the platform but it is fully integrated, whilst in the former case of the Mechanical Turk each connection is self-standing (no need for coordinating the offer).

Other platforms support the negotiation of the work by those who are controlling the offer. Hence, these platforms aggregate the demand side and let the offer side have the visibility on the demand allowing them to establish the connection and negotiate the deal. An example of "separate" offer is the one provided by Upwork, where the offer side can "show" their wares (skills and services that can be provided) and the demand side can enter in contact with the offer to start a negotiation. Other platforms are supporting negotiations but do that in an integrated way, like Twago. In this case the demand (the customer) explain the needs and the platform works out a possible offer that will then be negotiated by the customer directly with the freelancers involved.

As shown, there is a significant evolution ongoing in the Gig Economy and this is expected to characterise the work landscape in this decade (and the following ones). It is obvious the dramatic effect on work processes, on the workforce and on the work environment that this evolution implies.

It is also important to notice that the expansion of the Gig Economy is enabling the access to the offer of services by a multitude of people that before had no way to offer their skills. This is true both for the ones that using the cyberspace can offer their skills to the world market (a software developer in India can sell her skill to companies all around the world based on spot-demand) and for people offering their skills to a local area, like Go-Jek, that with a team of 200 engineers has set up and operates a platform managing 100 million order per month and coordinating over 2 million drives (in Indonesia). The amazing thing is that it basically created from scratch 2,000,000 + jobs in 10 years (the company was founded in 2009). By slashing transition cost these platforms enable a very effective connection of offer and demand increasing the marketplace, a crucial aspect in emerging economies.

At the same time the evolution of the Gig Economy towards high skill markets transforms single individuals in their own entrepreneurs. This is a very important evolution that is going to change, in a dramatic way, the work landscape in developed countries and that responds to the before mentioned evolution in distributed knowledge and human cloud. In a way we could say that the present evolution of the Gig Economy is a response (enabled by technology) to the increasing knowledge distribution, rapid obsolescence and human specialisation requiring access to a dynamically evolving human cloud.

e) Artificial intelligence driving automation

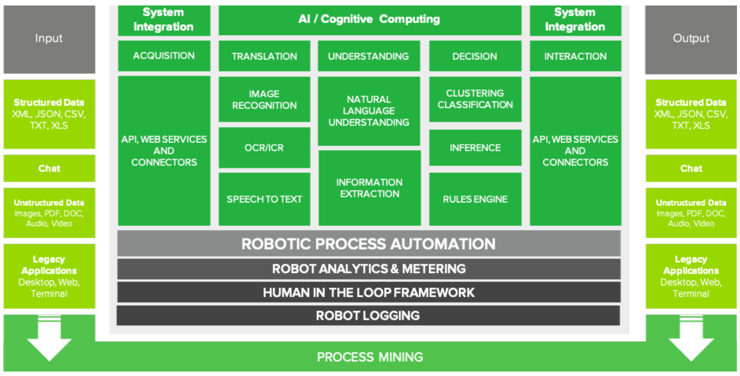


Fig. 100 A general framework for Intelligent Process Automation, layered on Robotic Process Automation. Artificial Intelligence supports specific functionalities and creates an emerging, cognitive intelligence. The graphic outlines a comprehensive architecture identifying the various components that are embedding artificial intelligence. [Image credit: Reply]

Many industries have adopted automation in both production, using robots - RPA: Robot Process Automation -, and document flow (process automation). This has had a significant impact on the workforce, both in terms of downsizing (activities moved from blue collars to robots and from white collars -clerks- to computers and data bases) and in terms of required skills (interacting with robots and computers require specific skills and training).

In the last decade, artificial intelligence has become a service either located in specific AI service providers /data-service centre or embedded in tools used by industry (smart robots, smart applications ...). What it is expected in this decade is for AI to take a seat in the control room of companies, being fed and learning, by multiple data streams, most of them internally generated by employees, machines and processes. This is known as IPA: Intelligent Process Automation.

The reality of today's business world, and even more so tomorrow, is the flooding of data. Everything is either creating data or being "substituted" by data (mirrored and operated through its mirror image). The Digital Transformation is at the core of this

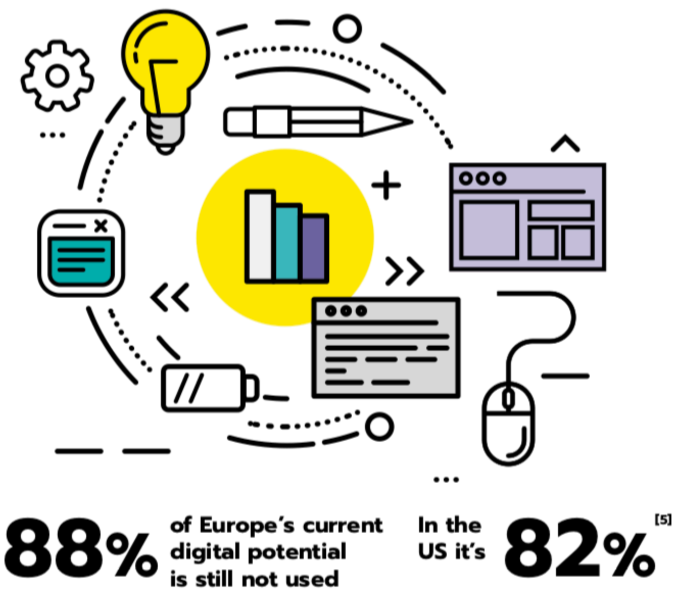


Fig. 101 There are plenty of unexploited opportunities in the digital space. Image credit: Talent Alpha

trend. However, analyses show that only a fraction of the digital potential offered by this world of data is actually being exploited. According to a report by Talent Alpha on "[7 drivers shaping the future of work]" 88% of Europe digital potential is not used, and the US are not much better exploiting just 18% of their digital potential.

A fundamental issue is that there are just too many data, and their sheer volume is beyond human capabilities. Hence the need to turn to artificial intelligence, not for replacing "human intelligence" but to do something that humans cannot do and return an intelligence that can interact with the human's one. This is addressed in the next section.
The point now is that by using artificial intelligence to continuously explore the data landscape it is possible to extract and contextualise meaning in ways that have not been possible before (also because te amount of data available today was not previously available).

Consider the example of a self-driving car. The car has to harvest internal and external data and make sense out of them to take decisions.

Consider the example of a self-driving car. The car has to harvest internal and external data and make sense out of that to take decisions.

CAR AUTOMATION SENSORS & DATA VOLUMES

Sensor type	Quantity	Data generated
Radar	4–6	0.1–15 Mbit/s
LIDAR	1–5	20–100 Mbit/s
Camera	6–12	500–3,500 Mbit/s
Ultrasonic	8–16	<0.01 Mbit/s
Vehicle motion, GNSS, IMU	-	<0.1 Mbit/s
TOTAL ESTIMATED BANDWIDTH		
3 Gbit/s (~1.4TB/h) to 40 Gbit/s (~19 TB/h)		

Fig. 102 Snapshot on the amount of data produced by sensors in a self-driving car. The total amount is impressive (with the lion's share played by the video cameras): a hour drive produces between 1.4 and 19 TB of data. Image credit: Tuxera

For this there are plenty of sensors, as shown in figure 102:
- Radar, for obstacle detection
- LIDAR and Cameras, for creating a map of the surrounding environment
- Ultrasonic, for near field obstacle detection
- GNSS (Global Navigation Satellite System) and IMU (Inertial Measurement Unit) to pinpoint the car position

The above sensors are just for providing context awareness. In addition the self-driving car control unit needs to have a digital model of the car describing its shape, volume, performances and needs to have data from the various active parts (like the engine, wheels, brakes, suspensions....) in order to know the slate of possible actions.

As indicated in figure 102 the amount of data is huge. Most of these data are time sensitive and lose value after a little while (once the car has left an area all the relative data are no longer useful). However, the combination of the data acquired with the result of actions taken by the car provides further data that increase the experience, hence allows the car, the auto-drive system, to learn. The learning can be shared with other cars, thus increasing the speed of learning and preventing wrong decisions in cars that will be facing a similar situation for the first time.

What goes for a self-driving car goes for airplanes, trains ... and of course it goes for robots in a manufacturing plan.

In the case of self-driving cars most of the decisions are local - taken by the car, in the car- (very limited amount of shared decisions with other cars, also because a self-driving car cannot assume, it would be wrong!, that other cars can share data and decisions, nor be notifiable of decisions taken). Most importantly, there are parameters that are completely out of a system wide analysis possibility, like pedestrians, bikers, dogs,... It is obvious that a car cannot communicate with any of these, needs to make some assumptions, and play it safe. In the case of airplanes the overall system is much more controllable (with the exception of taxiing, but here there are some studies to do that) and there are systems for autonomous aircraft to aircraft communications, like the TCAS - collision avoidance system.

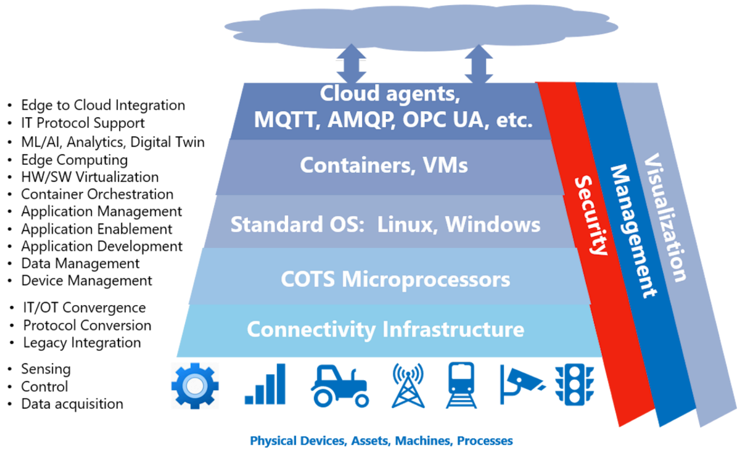


Fig. 103 Schematics showing a layered architecture for automation in factory/industry environment based on IIOT. At the lowest layer is the connectivity infrastructure, LTE or (private) 5G, then data processing and integration through commercial off-the-shelf computers -COTS-, operating systems, Virtual Machines and Containers, with the upper layer connecting through a variety of protocols to the Cloud/ Edge where AI takes over the data analysis and learning. Image credit: ARC Advisory Group

In an industrial environment, on the shop floor, in assembly lines, in warehouses, there is a growing flow of data, courtesy of IIoT - Industrial IoT, that can easily exceed the ones produced by a self driving car.
These data are being used for:

- *descriptive analysis*, providing info on what is happening and what happened (inventory, failures, output demand....)
- *predictive analysis*, providing info on possible malfunctions, output request by single machines over the coming weeks, resources, including workforce, needed in the coming weeks...
- *prescriptive analysis*, providing info on when to activate procurement, and where to procure, activation of pre-emptive maintenance, different allocation of resources, fine tuning of processes...

In all three areas there is a growing use of artificial intelligence to support the automation of the various processes involved.
Notice that the trend on the shop floor (and in manufacturing in general, along with the Industry 4.0 paradigm) is to analyse the whole picture and act directly or indirectly on the whole picture, sometimes involving suppliers and dealers (up to the user).
The intelligence needed is not the one localised in a machine (robot), in a plant, in a supplier... rather it is the emerging intelligence deriving from the cooperation of all "intelligent components".
This is the big challenge ahead for industry (that is what Industry 4.0 is all about) and in this decade we can expect an increased automation at the global level, throughout the whole value chain. The starting point, obviously, is the emerging intelligence on the shop floor, in warehouses, in the supply and delivery chain. These separate intelligences (each one with a specific "owner") will cooperate resulting in a global emerging intelligence.

This clearly has an impact on the workforce, since automation is shifting control activity from humans to machines (to the Cloud and Edge). In the past decade we have seen automation affecting at the micro scale, a robot replacing a worker/a team of workers. Now we are facing process automation that simply renders several activities unnecessary. The use of Digital Twins is further accelerating the shift to the cyberspace and accelerate process automation.

f) Distributed knowledge shared by humans and machines

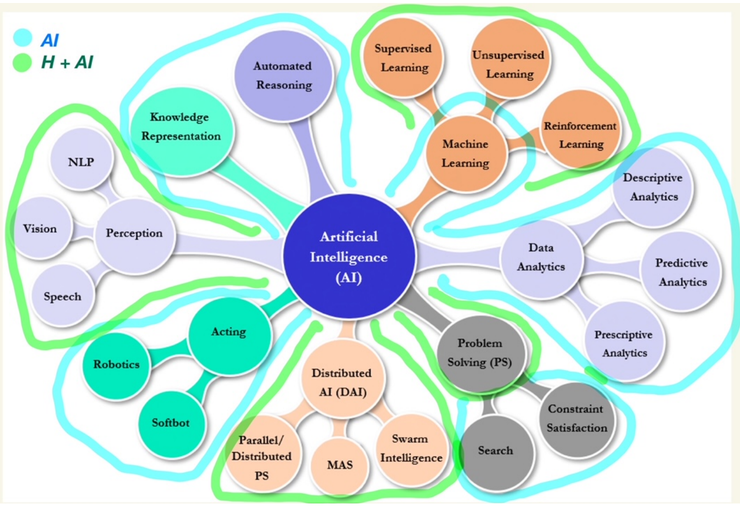


Fig. 104 A graphic showing the broad spectrum covered by Artificial intelligence. I have marked in blue the areas where AI is most likely to take the upper hand in this decade on the workplace nd in green the ones where cooperation between human and AI would result in human augmentation. Loss of jobs due to AI adoption can be expected in the blue areas, increased productivity through human-AI cooperation in the green areas. Image credit: LaptrinhX, marks by me

Artificial intelligence is becoming more and more pervasive and able to pick up a number of activities that up to now have been carried out by us (humans). This is the "automation" part of the story and automation is no longer restricted to manual activities but, because of artificial intelligence, is expanding to soft, mental, activities. In other words we are moving from muscle automation to intelligence automation.

As shown in figure 104, artificial intelligence covers many areas: in some the prevalence of AI over human intelligence is evident, in others we see an advantage in a cooperation among the two.

Prevalence:

- Machine control. The speed required in controlling the operation of robots or of softbots is making impossible to use human intelligence. The human may define the operation framework and impose some boundaries that once reached impose a stop to the machine, but in normal operation artificial intelligence is at work.
- Searching and evaluating is beyond human capability once the data set exceeds certain volumes, and this is more and more the case. In these situations the humans can provide the search criteria and the boundary conditions but the actual search can only be performed through AI. A "human-google" is simply impossible.
- Data analytics (descriptive, predictive and prescriptive) is also beyond human capabilities because of the huge volumes involved. Again, humans can define some targets (what is the goal of the analytics) but have to rely on AI for the actual data crunching.
- Machine learning, by definition, is in the realm of AI. However, as noted in the graphic, machine learning can be leveraged to contribute to the human learning and vice versa, humans, by identifying contexts and data sets, can steer the machine learning. Notice that the recent use of GANs is decreasing the human role in steering the machine learning (it remains however the role of humans in the definition of "what should be learned").
- Automated reasoning and knowledge representation (in machine readable form) are clearly in the specific field of AI.

Cooperation:

- Natural Language Language Processing - NPL-, Vision (image and context recognition), Speech (voice recognition) are all contributing to context perception (meaning, emotion detection, feelings,...). These are areas where humans show greater capability "in the small", meaning that in single instances humans are far better in converting the flow of "data" into a perception of "what is going on". However, “in the large" humans are limited in their ability of processing. As an example, a single person can only understand a few languages, AI can process a hundred of them, a human can follow a very limited number of parallel conversations, signal processing can separate a flow of voices into streams and a NPL application can be instantiated as many times as needed to process all streams in parallel. Vision acuity of humans is limited, the one of machines can be expanded over the human limits... For this decade, at least, cooperation of human and machines, with machines performing bulk work and humans finely tuning results would lead to best result. Furthermore, the capabilities of machines to use voice based and visual clues communications improve the possibility of collaboration with humans. Chatbots are an example of application.

- Problem solving is an area that often requires stepping out of the box, leveraging on creative thinking, something that human (experts) are usually better than machines. At the same time, the evaluation of a possibile solution and of all the implications/requirements may require in depth analyses and huge data crunching (like cost evaluation, supply chain re-engineering, weak effects impacts...) something that machines are better and faster. Hence a tight collaboration with humans exploring the big pictures and machines working out the details and performing simulation is likely to be the way to go for this decade (and the following ones). However, humans will need to learn to use "machine intelligence".
- Learning (supervised, unsupervised, reinforced) has been a characteristic of humans but AI has made huge progress in this area, becoming faster and faster (it takes years to an individual to become a master of chess/Go -and only very few can/will, a machine can become as proficient as a master in 24 hours). However, AI can be used by humans to accelerate their learning processes and most definitely can be used to flank and complement their knowledge. Learning knowledge is more and more associated to learn how to access -and make sense of- knowledge. This, and future decades will be characterised by the augmentation of human knowledge through machine.
- Distributed Intelligence (DAI-Distributed AI), Parallel/Distributed Parameter Servers, Multi Agent Systems and Swarm Intelligence are technologies in rapid evolution to deliver better AI. Distributed Intelligence is also a characteristic of human societies and communications infrastructures, digitalisation of knowledge and knowledge organisations (like Universities, IEEE, research centres, Open research frameworks) have increased enormously the leverage on distributed intelligence. The difference from the past (technology has always played a role in growth and leverage of distributed intelligence, think about the invention of writing, books, printed press, mail services, telecommunications, internet) is that now and in the future it becomes possible to have a distribution of intelligence involving machines and humans as intelligent nodes (machines until few years ago have been "repository", not active node of intelligence).

In assessing the impact on work and workforce of a distributed knowledge (and intelligence) shared by humans and machines we should also consider the differences between the two (the idea that artificial intelligence is a replica of the human one has lost appeal, we are now looking at two different, although valuable, forms of intelligence):

- Creativity, serendipity - on the human side these characteristics are not just important, they seem to be an integral component of human intelligence. It is the capability of imagination, of thinking out of the box. Machines' intelligence is lacking these characteristics, although we see results of AI that are similar to result of creativity, like music composition, paintings, even poetry.
- Creativity as self-fulfilment, self-motivation - on the human side we see that creativity is leading to more creativity through a process of self-appreciation (pleasure of having done

something). This is completely missing in machines (an algorithm is not "happy" nor feeling good after having achieved a result).

- Cost - intelligence is engrained in humans from birth and just keeps "growing", it does not cost anything. On the other hand, the cost associated to the growth of intelligence, time, investment in learning, exposure to specific experiences is really high and grows exponentially (human intelligence tends to grow asymptotically, after a while, each further tiny increase requires more and more effort). On the machine side, artificial intelligence has huge upstart cost but then it runs basically for free. Creating an artificial intelligent algorithm is quite complex and the cost can vary significantly, depending on the quality of data available and several other factors. In this decade the cost is likely to decrease and more and more companies will be able to develop their "local" intelligence. Bringing together, aggregating, several intelligences will remain for awhile a research endeavour, something that is being addressed in the FDC Digital Reality Initiative in 2021.
- Permanence of knowledge and intelligence- human intelligence is tied to a specific person, moving it from that person to another one takes a lot of time and the results are not guaranteed. On the contrary, moving intelligence from one machine to another is quite straightforward. Transfer human knowledge is likewise time-consuming if attempted directly, from one person to another (it depends on the existing gap of knowledge between the two persons and on how receptive the receiving person can be), much more effective if it is done through a medium (the first person writes down the knowledge on a book and other people can read that book to acquire the knowledge) but still quite time consuming (both in writing and reading/learning). Also notice that not all knowledge can be transferred through a medium. You can read a whole enciclopedia on how to ride a bike but you will discover that you cannot learn to ride a bike unless you try it over and over.

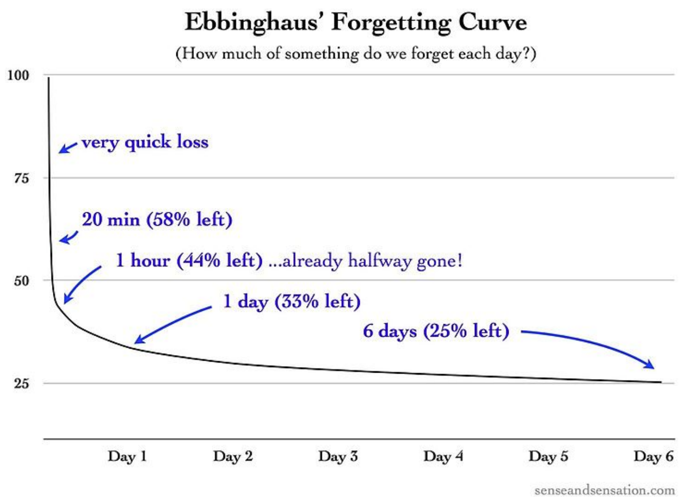


Fig. 105 Representation of the Ebbinghaus "forgetting curve". We tend to forget pretty quickly what we are learning, halving the retention after an hour and retaining just one fourth after one week. Image credit: senseandsensation.com

Another aspect of human knowledge is that over time we forget ... In case of machine the transfer of knowledge is easy and machines don't forget… The distribution of intelligence and knowledge among human and machines can also be used as a continuous refresher of the human's memory, increasing intellectual performances, in a way augmenting human memory.

g) Working with smart machines

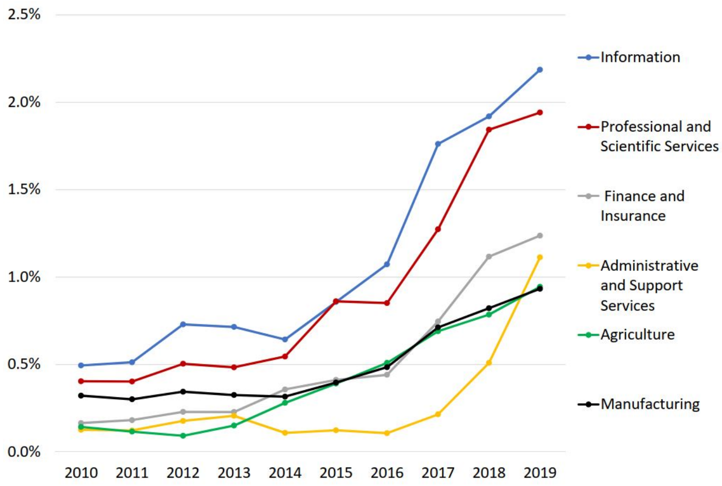


Fig. 106 Demand for AI skills across industries. Notice the increased growth of demand and how it is accelerating. Notable the acceleration in the administrative/support services sector. Image credit: Liudmila Alekseeva et al. The demand for AI skills in the labour market. VoxEU

From what I have discussed it is obvious that in this decade work will be intertwined more and more with intelligent machines (Machines used to include both hard -robot like- and soft -applications).

As pointed out in previous sections, artificial intelligence extends the applicability of automation and in doing so some jobs are lost. At the same time the growing use of AI stimulates growth of jobs in companies providing AI based systems and companies using them are on the quest for AI skills, see figure 106 showing the increasing demand for AI skills in several industry sectors in the US.

However, most of the impact of AI is going to be felt in the way work is performed and mostly by high-skills jobs, the ones that so far have not been affected by automation.

Let's look first at the way work changes as result of AI and of the Digital Transformation (fuelling AI and integrating AI into work processes) and let's use as an example the evolution of work in a manufacturing industry.

Today we have plenty of robots on the shop floor, in warehouses and in the supply/delivery chain. Each of these robots has a certain level of autonomy that will increase over the coming years. Interaction with blue collars is taking place at "machine level". There are meters to be red, levers to be pulled, buttons to be pushed, dials to be turned… (figure 107 - 1)

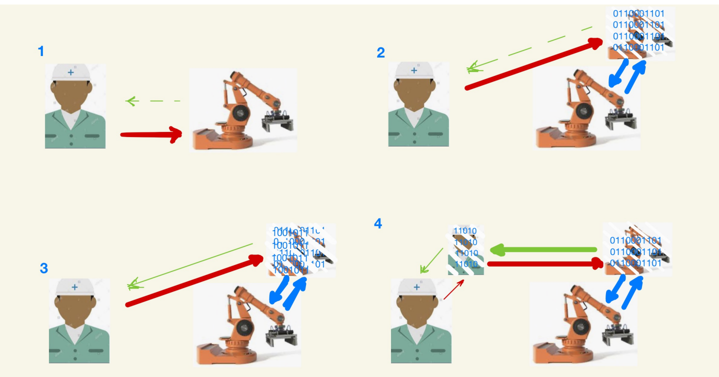


Fig. 107 Expected evolution of automation involving Digital Twins. 1: the human worker controls the machine and looks at how the machine operates (dashed green line). 2: the machine has a Digital Twin and the human workers interacts with the machine via the DT. Using AR the human can explore the DT. 3: The machine's DT is an active component of the machine and manages the interaction with the human worker (solid green line). 4: the human worker is also associated to a DT and this DT interacts with the machine's DT

What we are seeing is that machines are progressively equipped with a Digital Twin that models their behaviour, mirrors their status (DT at stage III) and progressively participate in the delivery of functionality (DT at stage IV). By the end of this decade we will likely see this DT cooperating with other DTs on the shop floor and beyond (DT at stage V).

Blue collars can interact with the DT, since this one can provide more information on the status of the machine. The data provided by the machine (through shadowing, ensuring a real time mirroring of the status of the machine) can be interpreted using AI to create a

meaningful interpretation of what is going on. As an example, a meter indicating the temperature inside a component of the machine (that was read by the blue collar in case 1) can now be correlated by AI to other parameters resulting in a situation awareness that can be much more meaningful to the blue collar operating the machine. The interaction with the DT can occur via a normal screen reporting images and text message or, better, it can be provided via AR goggles that let the blue collar look "inside" the machine "seeing" both the temperature and the potential impact on other components. This is represented as case 2 in the drawing. Notice the green dashed line indicating that the initiative is on the blue collar and there is not an interaction from the machine (nor DT) but this is resulting from the proactivity on the human side. Also, the same digital twin can be inspected by a white collar, like a designer, to verify what is the actual behaviour of a product using VR (since the white collar will not be co-located with the machine).
A more advanced situation occurs when, case 3, the DT achieves stage IV. At this point some of the functionality of the machine can actually be implemented (co-implemented) by the DT that will now autonomously interact with the blue (or white) collar (solid green line) when the need arises.

Further down the lane, by the end of this decade, many workers will have their own personal DT, PDT. In this case (case 4 in the graphic) the interaction may occur between the machine DT and the worker PDT that in turns will convert the information into a personalised information to maximise the effectiveness of the interaction. As a trivial example, two workers accessing the same machine could get the information in two different languages, because one is an Italian worker and the other a Korean one. The machine is being used in an Italian factory and was produced by a South Korean company. The same event may require the notification to both the user (Italian) and producer (Korean) for different purposes, like the user will need to be notified that a fine tuning is ongoing that will increase the yield, so that more pieces will be produced in the next 24 hours and the producer is notified of the increasing yield resulting from that fine tuning. The fine tuning and the decision on who should be informed is driven by AI and the actual flow of information is the result of adaptation taking place in the PDTs.
Although this example is a trivial one it helps in imaging how much the working environment will be changing in this decade and how much more interconnected the various players will be. This calls in the aspect of open data and this is a double edge sword. On the one hand open data increase the value of data by bringing in more players that can invest and create services but on the other hand the protection of data becomes trickier.

Whilst today a factory is a closed environment, controlled, with well defined processes and it is clear who has access (and responsibility) to what, in the future machines and humans will be sharing responsibility through data and these data can be visible to third parties) like the manufacturer. Notice that today we are seeing this happening (may be not perceiving) when using an

Fig. 108 A schematic representation of a multi-cloud systems with locations in several Countries offering object-storage services in line with [Gaia-X architecture](). Image credit: Pierre Gronlier, OVH Cloud

app on our smartphone or PC. The producer of that app most likely will get info on the way we are using it, on possible problems. This is (I hope so) for improving our app performances and fixing bugs, yet it opens the door to unexpected side effects.

Industry 4.0 is facing these kinds of issues, healthcare with personal data shared with a number of players (doctors, hospitals, pharma, health institutions) is another point in case. Workers will need to understand the broader implications of their activities.

Work is going on within the European Union to define a comprehensive architecture for data management (sharing, protection, ownership) based on a distributed cloud and a federated data infrastructure, [Gaia-X.]() It is now involving hundred of European and non European companies and is being "tested" through a number of use cases, including manufacturing and healthcare.

h) Working in a smart environment

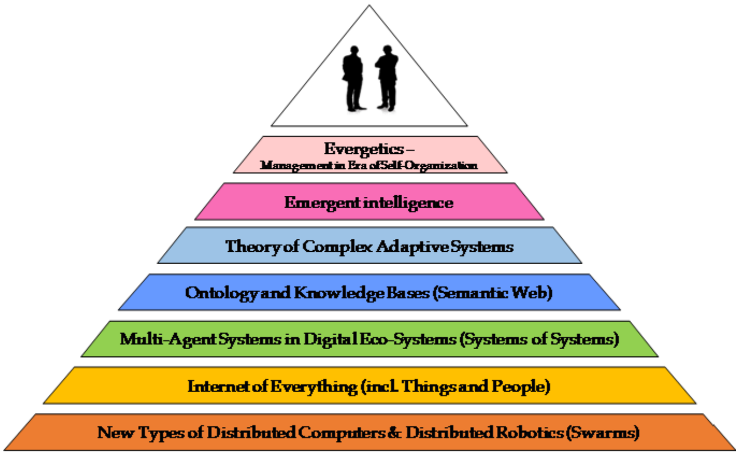


Fig. 109 From Digital Manufacturing to Digital Society. The various layers composing a Digital Society. At the bottom, as enabling infrastructure, distributed computing and Robotic Swarms, Internet of everything to include Things and People, Digital Ecosystems whose players interact with one another via Agents, a reference model for data (ontology and semantics), organisation through theory of complex systems giving rise to an emerging global intelligence and a the top a self organising management. Image credit: P. Skobelev and Borovik S. Yu.

It is well known that human societies progress through a continuous interaction among minds (people) and resources. Increasing one or the other, or both, without an effective interaction leads nowhere.
Hence humans are more than used to exploit distributed intelligence, the one present in other humans in the group. Actually, some people were/are used to "harvest" intelligence from animals, as an example: by looking at their behaviour they could infer a possible danger ahead.

Over the past century we have learnt to get information from a variety of sensors and by processing the data we have been able to be smarter. As these sensors became more sophisticated they both provided better data (covering more and more aspects of the real world) but they have also become more and more difficult to interpret (think about the data provided by sensors in a car, or in an airplane: it would be impossible to make use of the data they provide in real time, we have to rely on a computer to harvest and process them). This has opened the door to interaction with computers to retrieve and make sense of information/knowledge. We have been moving to use computers because they are fast and can react in real time, to using computer because they can correlate huge quantity of data and make sense of them and we are progressively relying on computers (AI) because they can make sense out of data and evaluate the best course of action in a given situation, in other words because they have become "intelligent". More and more, computers (devices embedding computers) are becoming autonomous and take decisions based on their perception of the context (context aware) and on the goals that have been defined.

Now, the point is that when you have several autonomous systems, each of them context aware, you have a situation where the action of one system affects the context and therefore influences the actions of the other systems in that context not by direct interaction but through change in the context. We, humans, are autonomous systems and as such we use context awareness (quite often) to tune our behaviour. I would say that most of our life is based on context awareness and adaptation, only a minimal part is based on explicit interactions.

Fig. 110 People walking in a crowd automatically adjust their movement based on the context. Most people will tend to occupy the central space so that in a station, as shown in this photo, people getting out of the train will walk in the central part of the corridor forcing people moving towards trains to walk on the sides. It is an example of a swarm behaviour/intelligence. Image credit: DNYUZ

Think about walking on a pedestrian road. You are among hundreds of other people, moving in a seemingly random directions (at least this is what I feel sometimes...). You never stop asking the other person what are his plans so that you can avoid bumping onto him. Nor is he asking you. And yet, seamlessly, we manage to go our way without hitting anybody (well, most of the time…). This is what is known as the swarm intelligence. The behaviour of each participant in the swarm affects the behaviours of he others and in turns this creates an emergent behaviour (intelligence) of the swarm. This also applies to knowledge (and culture): by living in a certain environment you absorb the knowledge and culture that is at the core of that environment societal behaviour (by living side to side with a mathematician you are not going to "learn" differential equation by proximity, but over time you learn to "think" in a certain way...). This is also one of the reasons why remote working is not the same as working in the same space and both companies and workers pointed this out during the lockdown we have experienced in the Covid-19 pandemic. The smart of the crowd, of the swarm, is lost when proximity is lost.

In this decade workers are going to make higher use of telework but companies will need to find ways to restore the swarm intelligence. The evolution of collaborative tools has increased rapidly in response to the pandemic and quite a few have tried virtual spaces. So far nothing has emerged as being capable of restoring the benefits of proximity but we should get closer, by the end of this decade. VR could potentially play a significant role providing more credible virtual presence in a community but we are definitely not there yet.

Fig. 111 The Baxter co-bot has been designed with some anthropomorphic traits, a screen is used as a head to convey a sense of attention, emotion.... . Image credit: Rethink Robotics

This seamless influence in a crowd/ team is not available among people and machines, so far. People today experience a gap between themselves and machines. Co-bots are being

designed to operate seamlessly with workers, some are even giving some anthropomorphic traits to robots, like Baxter, see figure 111. The use of voice interaction is surely going to increase the effectiveness of interactions. The use of artificial intelligence and NLP (Natural Language Processing) along with the capability of distinguishing various streams of speech (as humans do, focussing on a specific conversation out of many) will further improve seamless interactions.
The availability of a pervasive, high-bandwidth, communication infrastructure is making possible to connect, in a seamless way, local intelligence (both machines and humans) creating a swarm in the cyberspace and letting local intelligence to become augmented by accessing the emerging intelligence of the swarm. The crucial point here, for an effective smart ambient, is "seamless": people should not perceive an interface, they should just "live and act" in a context and the smartness of the context is actually increasing intelligence to each person (and machine). An example of this "swarm intelligence" is provided by Unanimous AI. Through software (including AI) Unanimous AI leverages the distributed intelligence of a crowd complementing it with the intelligence of machines.

Fig. 112 A screenshot of the Swarm Intelligence interface. Each participant contributes to the total intelligence, including the one generated by machines or autonomously by the system.
Image credit: Unanimous AI

As an examples practitioner medical doctors can interact (via voice or through a screen, see figure 112) with Unanimous AI Swarm Intelligence (customised to fit the needs of healthcare practitioners) and share experience or formulate questions. The long term view would be to have a presence of tendrils of this swarm in the studio of the doctor to pick up all conversations, record all exams and their results, pick up the voice of the patient.... (all of this is not done at the moment, connection to the system requires an explicit action by the doctor -this, by the way addresses also privacy issues...). The Swarms collects and cross checks all these data and autonomously peruses the thousands of medical articles in medical journals, cross references drugs and their effect as tested in the labs and experienced in the field. This knowledge, and intelligence, is made available to doctors.

The approach to emerging intelligence via a swarm can be applied to a variety of context and I feel we are going to see plenty of it in many areas, transforming the working place and the way of working by the end of this decade.

23. Conclusions

The future has not been written yet, it will happen day by day. Hence, all these Megatrends are to be taken with a grain of salt. Some of these may prove to be too ambitious or quite simply the cultural and economical landscape will no longer be conducive to their realisation. The economic resources that will be needed to recover the pandemic losses may limit the resources needed for innovation in certain areas but may increase innovation effort in others. Others may actually be implemented well before the end of this decade, the current pandemic has created a disruption that shifted focus, needs and funds in ways that were unexpected in 2019. It may turn out that the pandemic effects will be transient and life, and roadmaps, will be restored as if nothing happened (I don't think so).

The aim in presenting these Megatrends is to stimulate discussion. Quite a bit occurred when I presented the various chunks in a series of posts on the FDC website. I hope that having collected them all into a single document may help in reasoning about the forest and stimulate new ideas.

In the Digital Reality Initiative we are going to address a number of the topics mentioned in this ebook, particularly the ones related, or influenced by, artificial intelligence. Others are being addressed in the many IEEE Societies that every single day bring together thousands of engineers from academia and industry that are building the future, for all of us, a future that each one of us has the responsibility of shaping.

The first step is imagine what it could be.

Appendix - Technology legacy from the last decade

To put the discussed Megatrends into a perspective of the legacy they can leave to the subsequent decades it might be worth looking back at the last decade and consider what happened from a technology point of view that left an lasting imprint on the current decade:

- the first iPad was released on April 3rd, 2010. I still remember Steve Jobs' presentation promising that "it would feel like holding the Internet in your hand and a change in the way we will look at the web from there on". It turned out he was right;
- last decade was the one that saw the shift from 3G to 4G. It took ten years to complete (it is not yet fully complete but we can say that 4G is now the "norm"). That increased by 10 times the download speed, from 1.5Mbps to 15Mbps (what took 5 hours to download could now be done in less than one minute). Who benefitted from this shift? Clearly all of us, as users, as well as industries in the areas of content delivery, eCommerce, social media and smartphone manufacturers. Strange enough, Telecom Operators did not benefit from the increased performances *they* provided, actually all of them saw their revenues shrinking, courtesy of the digital transformation;
- smartphones took over the plain vanilla cellphones. In 2010 296 million smartphones were sold worldwide, their number increased to 1.5 billion sold in the year 2015. In the last 6 years the number of units sold has remained basically constant, between 1.5 and 1.6 billion units. Interestingly the top of the line smartphone cost has kept increasing, doubling in the last 5 years, but at the same time basic smartphones price has gone down, under 100$ (the cheapest smartphone in India in 2021 goes for 60$), making them affordable for third world countries and leading to a replacement of cellphones with smartphones. By the end of 2020 63.6% of people in the world (that includes everybody, newborn as well) have a mobile phone and 48.5% are using a smartphone (in other words almost 78% of all mobile phones are smartphones);
- smartphones, tablets and 4G have increased the time we spend on a mobile device from an average 32 minutes in 2011 to 132 minutes -daily- in 2019 (worldwide average). In 2019 people in the US have spent more time using a mobile device than watching TV, for the first time ever;
- point and shoot digital cameras peaked in market volume at the beginning of the last decade and have now basically disappeared, killed by the digital cameras in the smartphones. They disappeared in just a few years, between 2013 and 2016;
- smart home assistant were basically not existing at the beginning of the last decade. Alexa was released on November 6th, 2014. Voice controlled devices were born in the the last decade, nowhere to be seen in the previous one. Today we control our television, appliances, car entertainment system via voice;
- In 2016 Google released GNMT, Google Neural Machine Translator, that today provides translation among 109 languages. This has changed the world, although not many people have realised it. In this decade most people will experience this change, enabling real time communications by killing language barriers;
- in October 2009, an article on Fortune discussed the possibility to use a smartphone as GPS navigator, pointing out that it seemed like a crazy idea. Today, it is normal to use your smartphone as a GPS navigator, it has actually become better than the one we have in our car (because it is updated in real time, it has extra features, like search by place, rather than by address, you can see where your friends are ...). In this ten years adds on optional provided by car rentals for navigation services have disappeared (at least no one is buying them anymore...);
- television has shifted from analogue to digital in the last decade and it is now digital almost everywhere. 4K arrived in 2015 and it is now becoming a "standard" with 8k moving its first

step. Netflix started its international expansion on Sept 22nd, 2010, (Canada) and now it has become one of the largest worldwide player with over 182 million subscribers;

- social media have brought our lives on-line and are affecting each of us as individual and as part of a society. Their influence in politics and in business can non longer be ignored, as it cannot be ignored the power of those controlling the main social media platforms (the recent ban of President Trump from Twitter and Facebook is both a testimony of the power that can be exerted through social media and the power these platforms have to decide what is right and what is wrong....);
- CRISPR-Cas9 was "discovered" in 2012 and opened the door to genomics and precision medicine. stimulating both research and application. From zero papers published on this technology in 2012 we now have over 3500 papers being published every year (3000 in 2018), the Covid-19 Moderna and Pfizer vaccines have been using this technology;

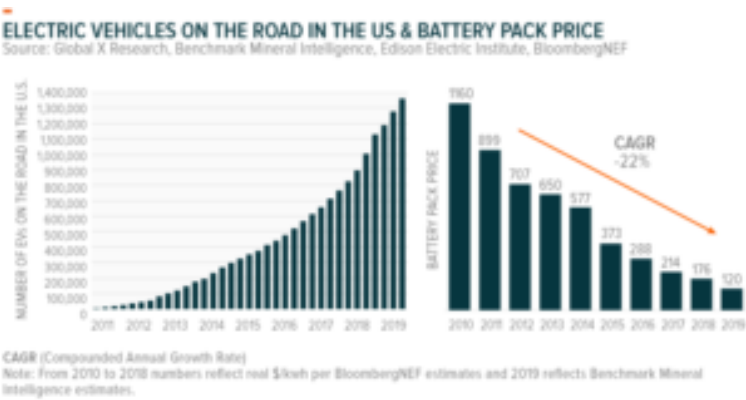


Fig. 113 The growth of electric cars in the last decade and the corresponding decrease of the price (expressed in $ per kwh) from 1120 to 120. Image credit: Global X Research

- In 2011 there were basically zero electric car on the road. At the end of 2020 there are some 8 million electric carsworldwide, just a tiny fraction of cars, but we are start noticing them. 2.1 million electric cars were sold in 2019, versus a total of 70 million. As said it is just a beginning, but it is going to reshape the industry in this decade. Interestingly, in the last ten years the price of the battery pack fell by one order of magnitude, at a CAGR of -22% (from 1,120 $ per kwh to 120$ per kwh);

- big data have become bigger, moving from 2ZB produced in 2010 to 41 ZB in 2019 (a doubling every 2 years): Interestingly whilst only 9% of data produced in 2010 were structured (i.e. usable by AI) 13% of those produced in 2019 were structured (that is 180 EB in 2010 vs 5,300 EB in 2019, a 30times factor growth). This increase has gone hand in hand with the increased performance of AI and its increased widespread use.
- GAN, Generative Adversarial Networks were "invented" in the 2010-2014 timeframe and are now starting to change the landscape of AI, making it possible to develop AI from a much smaller set of data, meaning that AI has no longer to be associated with the big guns of data (G-MAFIA and BAT).
- Data storage has definitely started to move to the Cloud. It was just 10% in 2010, by 2019 it grew to 70%. In the last decade the word "fog" to identify clouds at the edges started to be used and more and more interest is focussing on federated clouds and related aspects like edge computing, Software as a Service, Platform as a Service and Infrastructure as a Service.

List of Acronyms

AI:	Artificial Intelligence
AIaaS:	AI as a Service
ALS:	Amyotrophic Lateral Sclerosis
AR:	Augmented Reality
AWS:	Amazon Web Services
BCI:	Brain Computer Interface
CAD:	Computer Aided Design
CAGR:	Compound Annual Growth Rate
Cas9:	CRISPR associated protein 9
CAT:	Computerised Axial Tomography
CDT:	Cognitive Digital Twin
CEO:	Chief Executive Officer
CES:	Consumer Electronic Show
CO2:	Carbon Dioxide
CRISPR:	Clustered Regularly Interspaced Short Palindromic Repeats
DAI:	Distributed Artificial Intelligence
DFR:	Deposit Facility Rate
DNA:	DeoxyriboNucleic Acid
DRI:	Digital Reality Initiative
DT:	Digital Twin
DX:	Digital Transformation
ECB:	European Central Bank
ECG:	ElectroCardioGram
EHR:	Electronic Health Record
FAO:	Food and Agriculture Organization
FDA:	Food and Drug Administration
GAN:	Generative Adversarial Networks
GDP:	Gross Domestic Product
GPS:	Global Positioning System
KPI:	Key Performance Indicator
IFTF:	Institute For The Future
IMF:	International Monetary Fund
IoT:	Internet of Things
IPA:	Intelligent Process Automation
LIDAR:	Light Detection and Ranging
MaaS:	Mobility as a Service
MAS:	Multi Agent System
ML:	Machine Learning
MRO:	Main Refinancing Operations
OECD:	Organisation for Economic Co-operation and Development
OS:	Operating System
PC:	Personal Computer
PDT:	Personal Digital Twin
RAM:	Random Access Memory
RNA:	RiboNucleic Acid
RPA:	Robotic Process Automation
SAE:	Society of Automotive Engineers
VR:	Virtual Reality

WEF:	World Economic Forum
WHO:	World Health Organisation